FIRE DEPARTMENT

HYDRAULIC PROBLEMS,

AND HOW TO WORK THEM

For Civil Service Examinations for all Ranks and as a practical guide in the performance of every-day duty.

SIMPLE RULES AND METHODS FOR FINDING

Square Root—Friction Loss in Fire Hose, Water Mains, Standpipes and Fittings—Nozzle Discharge—Engine and Nozzle Pressure—Water Tower Discharge—Height of Streams—Pump Slip and Pump Displacement—Pump Capacity—Horse-power of a Fire Engine—Automatic Sprinkler Discharge—Fire Hydrant Discharge—Volume—Siamese Connections—Fire Underwriters' and other Tables, etc.

ANSWERS TO CIVIL SERVICE QUESTIONS ON HYDRAULICS AT FIRE EXAMINATIONS.

Illustrated by 21 full-page plates.

By CHARLES BLUM, B. S., C. E.

Bureau of Engineering, Department of Water Supply, New York City; formerly of the United States Engineering Service.

PRICE, TWO DOLLARS.

Civil Service CHRONICLE

23 Duane Street, New York.

FIRE DEPT. PROMOTION EXAMINATION INSTRUCTION

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CONTENTS.

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PREFACE.

The object of the author in presenting this work is to satisfy the growing demand among candidates in promotion examinations in the Fire Department, and also among officers to assist them in their work at fires, for simple methods, rules and formulae for solving hydraulic problems in a way to be understandable by those who have not had the advantage of theoretical training. It is the elementary principles of hydraulics that are desired by members of the Fire Department, and it is hoped that the present effort, the first of its kind that has yet been made, will satisfy.

The author, through a varied experience in taking civil service examinations and as a civil service instructor, has found that many members of the Fire Department fail at civil service examinations because they do not make their answers clear, and particularly in hydraulic problems through failure to show processes and methods of working. They forget that, no matter how well they may know the subject in their own way, the Examiner is guided solely by the written answer submitted to him.

Many Firemen know what factors to use, etc., but cannot explain why they use them. How many Firemen after using the factor .434 in solving a problem can answer the question, "Where do you get .434? What does it represent?" Some will say that it represents the weight of one cubic inch of water; others, that it represents the weight of one cubic foot of water; while it actually represents the weight of a column of water one inch square and one foot high. It is therefore neither a cubic inch, nor a cubic foot, and an answer which stated that it was a cubic inch or a cubic foot would not be rated as correct.

It is therefore important to understand the theory as well as the practice. Some of these problems can be worked by many methods, and the primary effort here has been made to give the simplest methods, while sometimes also giving a variety of methods.

Acknowledgment is made to the invaluable tables of the National Board of Fire Underwriters, taken from their "Red Book," "Fire Engine Tests and Fire Stream Tables."

CHARLES BLUM, B. S., C. E.

A FEW POINTERS.

(1) Study carefully the announcement of the examination.

(2) Prepare mostly on your weak subjects.

(3) Obtain all previous examination questions, rules, regulations, etc.

(4) Read the questions over carefully.

(5) Don't answer Question No. 5 under Question No. 3.

(6) Gauge your time; allow a proportionate amount of time to each question.

(7) When a question is not clear, answer in all possible ways.

(8) If a question is incomplete, complete it in your answer, and give your reasons for doing it.

(9) Don't wander from the subject at hand.

(10) All figuring should be on the examination ruled sheets.

(11) Show clearly the methods by which you arrive at your answers.

(12) Lengthy discussions are not desired; answers should be direct and concise.

(13) In calculating pressure, friction and resistance, wherever occurring, candidates must show clearly their processes or formulas used. A mere statement will not be considered an answer.

(14) Whenever possible, illustrate your answer by a sketch.

HYDRAULICS.

Principles of the Flow of Water.

1. *Hydraulics* are that branch of mechanics which treats of the laws governing the pressure and motion of water.

2. *"Head."* This is depth of water from surface to a point in question, or may be the difference in level or elevation between two water surfaces at the beginning and end of a pipe line.

3. *"Pressure"* is usually expressed in pounds. Pressure is due to the weight or head of water. The pressure in a unit of area, such as a square foot or square inch, is referred to as "Unit Pressure." As water weighs 62½ pounds per cubic foot, the pressure at any depth must be 62½ times the depth in feet, and on one square inch at the same depth, 1-144 of this quantity, which equals .434.

$$\frac{62.5}{144} = .434 \text{ lbs. per square inch.}$$

This pressure acts equally in all directions and is independent of the shape of the pipe or vessel.

Rule:—To convert feet of head to pounds pressure, multiply by .434.

To convert pounds pressure to feet of head, multiply by 2.304 or 1/.434.

4. *"Velocity"* is usually expressed in feet per second. This represents the rate at which the water flows through the medium in question.

It depends upon:

1. The head.
2. The force of gravity.
3. The character of the medium through which the water flows.

From the laws of falling bodies the *fundamental law of velocity* is found to be theoretically:

$$v = \sqrt{2\,g\,h}$$

v=velocity in feet per second.
g=acceleration of gravity=32.16.
h=head in feet.

To adapt this simple rule to various conditions, a percentage or coefficient (c) is applied to the theoretical velocity.

5. *"Discharge" or "Quantity"* is usually expressed in cubic feet per second, or popularly in gallons per minute. It represents the amount of water flowing through any pipe.

This is found by the rule:

$$Q = c\,a\,v$$

Q=discharge in cubic feet per second.
a=area of water section in channel.
v=velocity of flow in feet per second.
c=a percentage or "co-efficient," to adapt the rule to various conditions.

The head h, which is required to produce a given velocity v, is called "velocity head," as is expressed by the formula

$$h = v^2 \div 2g$$

obtained direct from previous No. 4.

6. *"Friction"* is usually in a percentage. The flow of water through any pipe is retarded by friction against the bottom or sides of same, and this reduces both the velocity and discharge.

Friction is a very important factor in pipe lines, and is proportional to the length of the pipe or hose. It varies as the square of the velocity. It increases with the roughness of the pipe. It decreases as the diameter of the pipe or hose increases. It is independent of the pressure in the pipe.

7. *Atmospheric,* or *Air Pressure,* is measured by the readings of the barometer. The liquid usually employed is mercury, which weighs 0.49 pounds per cubic inch at common temperatures. To obtain the value of atmospheric or air pressure, multiply the barometric reading in inches by 0.49. The average barometric reading near sea level is 30 inches. Thus:

$30 \times 0.49 = 14.7$ pounds per square inch, or one atmosphere.

8. *Absolute Pressure* is the sum of atmospheric pressure and the indicated gauge pressure. Thus, if the pressure gauge reads 20 pounds, the absolute pressure would be $20 + 14.7 = 34.7$ pounds per square inch absolute.

SQUARE ROOT.

Extract the square root of 26′52.25.

Rule:—Divide the number into periods of two places, starting from the decimal point to the left and to the right. This will give you 26 as the first period, 52 as the second period, and 25 as the third period.

Guess the nearest square root of 26. It is 5, or 5×5=25. Subtract 25 from 26, giving a remainder of 1. Bring down the next period (52). Then for a trial divisor multiply whatever is in the answer by 20. In this case 20×5=100 as the trial divisor, which goes into 152 about 1 time. Add 1 to the trial divisor, place in the answer, then multiply 101 by 1, which equals 101. Subtract, bring down the next period and multiply what is in the answer by 20 to get trial divisor, same as before, and so on.

Solution:

```
                   51.5
                ─────────
               √ 26′52.25
                 25
                ────
  20×5=100        152
         1
      ────
       101        101
                ──────
  20×51=1020       5125
           5
        ────       5125
        1025       ────
```

```
   51.5
   51.5
   ────
   2575
   515
  2575
 ───────
 2652.25
```

Proof:—51.5×51.5=2652.25.

FRICTION LOSS IN FIRE HOSE.

No recognized formula for determining the friction loss in fire hose where pressure, length and diameter are known, has yet been found. If there were such a formula, some value would have to be assumed for the co-efficient of friction between water and hose. This value would necessarily vary with the different qualities of lining of hose; also with the velocity of the water, for the eddy currents therein increase greatly with the velocity. Consequently, a theoretical value for friction loss would be so far from the real value as to be worthless.

Considerable pressure is lost by friction of water passing through long lengths of hose. Experiments by Freeman, which are used as a standard, show in a case where 200 gallons per minute were passed through several kinds of hose, the varying losses in pressure were as follows:

Unlined linen hose=27 pounds loss per 100-foot length.
Rough rubber-lined hose=26 pounds loss per 100-foot length.
Medium rubber-lined hose=12 pounds loss per 100-foot length.
Very smooth rubber-lined hose=10 pounds loss per 100-foot length.

Therefore, it can be seen at a glance that the difference between the worst and best hose is the difference between 27 pounds and 10 pounds, or a difference of 17 pounds.

Other conditions being the same, the loss by friction varies directly in accordance with the length of hose involved, 400 feet causing double the loss of 200 feet; 300 feet causing three times the loss of 100 feet, and so on. The friction also varies in the same size hose very nearly in accordance with the square of the velocity of discharge. That is: with double the velocity of discharge the loss of pressure is increased four times. For example, if a nozzle which will deliver 200 gallons per minute be supplied through a very smooth rubber-lined linen hose, the loss of pressure is 10 pounds per 100-foot length, and the pressure at the engine would have to be this amount higher than the pressure at the branch. Now, lay an additional line of 2½-inch hose to the branch, and the velocity of flow will become just one-half, or 100 gallons per minute in each hose, and the loss by friction becomes one-quarter of what it was originally, or ¼ of 10=2½ pounds, approximately.

Actual friction loss can only be obtained by actual test.

(Note:—Many years ago an order was issued in the New York Fire Department authorizing a rule to allow 7 pounds friction loss to each length of hose. This was never intended to be more than a rule for rough and ready calculation, and the fact that this did not take into considera-

tion flow, size of hose or size of nozzle resulted in many members of the Department using the Fire Underwriters' table as a substitute. The result of this was that at civil service examinations some candidates felt under obligation to use the so-called "Department Rule," while others used the accurate Underwriters' table. The 7-pound rule was never officially revoked until December, 1915, when an order was issued giving the rules to be found below.—EDITOR.)

The following rules are in accordance with Special Order No. 226, December 14, 1915, of the New York Fire Department. The official standards are printed in quotation marks, and are followed by problems by the author.

"TAKING 100-FOOT LENGTHS AS A UNIT:"
"FRICTION LOSS IN 3½-INCH HOSE."

"For a flow of 500 to 1,200 gallons per minute: For the first 500 gallons allow a loss of 9½ pounds, and for each 10 gallons over 500, up to 1,200, add 3-5 of a pound to the 9½ pounds."

Question:—What is the friction loss in 200 feet of 3½-inch hose for a flow of 520 gallons per minute?

SOLUTION:

For first 500 gallons, loss = ... 9.5 lbs.

For next 20 gallons, loss $= \frac{20}{10} = 2 \quad 2 \times \frac{3}{5} = \frac{6}{5} = 1\,1/5 =$ 1.2 lbs.

For 520 gallons, loss = ... 10.7 lbs.

For 200-foot length loss $= \frac{200}{100} = 2 \qquad 2 \times 10.7 = 21.4$ lbs. (Ans.)

"FRICTION LOSS IN 3-INCH HOSE."

"For a flow of 200 to 400 gallons per minute: For the first 200 gallons allow a loss of 4 pounds, and for each 10 gallons over 200, up to 400, add ½ of a pound to the 4 pounds. For a flow of 400 to 700 gallons per minute: For the first 400 gallons allow a loss of 14 pounds, and for each 10 gallons over 400, up to 700, add 4-5 of a pound to the 14 pounds."

Question:—(a) What is the friction loss in 150 feet of 3-inch hose for a flow of 400 gallons per minute? (b) For a flow of 600 gallons per minute?

SOLUTION:

(a) For first 200 gallons, loss = ... 4 lbs.

For next 200 gallons, loss $= \frac{200}{10} = 20 \qquad 20 \times \frac{1}{2} =$ 10 lbs.

For 400 gallons, loss = ... 14 lbs.

For 150-foot length, loss $= \frac{150}{100} = 1.5 \qquad 1.5 \times 14 = 21$ lbs. (Ans.)

(b) For first 400 gallons, loss = ... 14 lbs.

For next 200 gallons, loss $= \frac{200}{10} = 20 \quad 20 \times \frac{4}{5} = \frac{80}{5} =$ 16 lbs.

For 600 gallons, loss = ... 30 lbs.

For 150-foot length, loss $= \frac{150}{100} = 1.5 \qquad 1.5 \times 30 = 45$ lbs. (Ans.)

"FRICTION LOSS IN 2½-INCH HOSE."

"For a flow of 200 to 400 gallons per minute: For the first 200 gallons allow a loss of 10 pounds, and for each 10 gallons over 200, up to 400, add 1 and 1-3 pounds to the 10 pounds."

Question:—What is the friction loss in 250 feet of 2½-inch hose for a flow of 350 gallons per minute?

SOLUTION:

For first 200 gallons, loss = ... 10 lbs.

For next 150 gallons, loss $= \frac{150}{10} = 15 \qquad 15 \times \frac{4}{3} = \frac{60}{3} =$ 20 lbs.

For 350 gallons, loss = ... 30 lbs.

For 250-foot length, loss $= \frac{250}{100} = 2.5 \qquad 2.5 \times 30 = 75$ lbs. (Ans.)

ANOTHER SIMPLE METHOD FOR FINDING FRICTION LOSS IS AS FOLLOWS:

Friction Loss in 2½-inch Hose (100 feet long).

For 200 gals.	300 gals.	400 gals.	500 gals.
2	3	4	5
—	—	—	—
4	9	16	25
2	2	2	2
—	—	—	—
8	18	32	50
+ 2	+ 3	+ 4	+ 5
—	—	—	—
loss, 10	loss, 21	loss, 36	loss, 55

Friction Loss for 3-inch Hose (100 feet long).

For 200 gals.	300 gals.	400 gals.
2	3	4
—	—	—
loss, 4	loss, 9	loss, 16 (approximately)
500	600	700
5	6	7
—	—	—
25	36	49
— 5	— 6	— 7
—	—	—
loss, 20	loss, 30	loss, 42 (approximately)

NOTE:—Friction Loss in first length is usually greater than in other lengths, due to play pipe being attached to first length.

FRICTION LOSS IN FIRE HOSE.

BASED ON TESTS OF BEST QUALITY RUBBER LINED FIRE HOSE.*

Flow, Gallons per Minute.	Pressure Loss in Each 100 Feet of Hose, Pounds per Sq. Inch.				Flow, Gallons per Minute.	Pressure Loss in Each 100 Feet of Hose, Pounds per Sq. Inch.		
	2½" Hose.	3" Hose.	3½" Hose.	2 Lines of 2½" Siamesed.		3" Hose.	3½" Hose.	2 Lines of 2½" Siamesed.
140	5.2	2.0	0.9	1.4	525	23.2	10.5	16.6
160	6.6	2.6	1 2	1.9	550	25 2	11.4	18.1
180	8.3	3.2	1.5	2.3	575	27.5	12 4	19.0
200	10.1	3.9	1.8	2 8	600	29.9	13.4	21.2
220	12.0	4.2	2.1	3.3	625	32.0	14.4	23.0
240	14.1	5.4	2.5	3.9	650	34.5	15 5	24.8
260	16.4	6.3	2.9	4.5	675	37.0	16.6	26 5
280	18.7	7.2	3.3	5.2	700	39.5	17.7	28.3
300	21.2	8.2	3.7	5.9	725	42 3	18.9	30.2
320	23 8	9 3	4.2	6.6	750	45 0	20 1	32.2
340	26.9	10.5	4.7	7.4	775	47.8	21.4	34.2
360	30.0	11.5	5.2	8.3	800	50.5	22.7	36.2
380	33 0	12.8	5.8	9.2	825	53.5	24.0	38.4
400	36.2	14.1	6 3	10.1	850	56.5	25.4	40.7
425	40.8	15.7	7.0	11.3	875	59.7	26.8	43.1
450	45.2	17.5	7.9	12.5	900	63.0	28.2	45.2
475	50.0	19.3	8.7	13.8	1,000	76.5	34.3	55.0
500	55.0	21.2	9.5	15.2	1,100	91.5	41.0	65.5

*Rough rubber lining is liable to increase the losses given in the table as much as 50 per cent.

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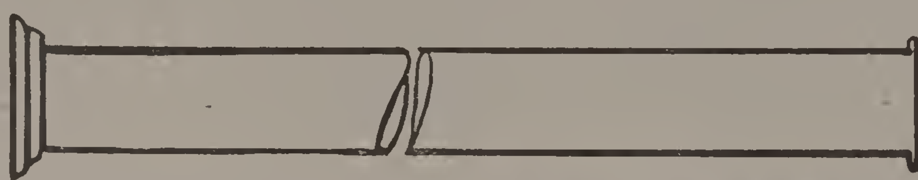


Friction Loss in Water Mains

Friction Loss in mains is proportional to the length of pipe; it varies as the square of the velocity; it increases with the roughness of the pipe; it decreases as the diameter of pipe increases; it is independent of the pressure in the pipe.

Friction Loss Formula:

Let - h = Friction head
" - L = Length of pipe = 1000 feet
" d = diameter of pipe in feet $\frac{9}{12} = .75$
" f = Coefficient depending on roughness of pipe = .02
" V = Velocity = 8 ft per second
" g = Gravity = 32.16 feet per second

Then $h = f \times \frac{L}{d} \times \frac{V^2}{2g}$

Problem: What is the loss of head due to friction in a 9" pipe, 1000 feet long, if mean velocity of flow is 8 ft per second? assume coefficient = .02

$$h = \underset{=f}{.02} \times \frac{\overset{=L}{1000}}{\underset{=d}{.75}} \times \frac{\overset{=V^2}{8^2}}{\underset{=2g}{2 \times 32.16}} = .02 \times 1333.33 \times \frac{64}{64.32} = 26.5 \text{ feet}$$

```
 1333.33
     .02
--------
 26.6666
      64
--------
 1066664
1599996
--------
1706.6624
```

```
64.32)1706.6624(26.5+  Ans.
      12864
      -----
       42026
       38592
       -----
        34342
        32160
        -----
```

FRICTION LOSS IN STANDPIPES.

Friction Loss in Standpipes may be taken as follows for each 100 feet of length:

	Friction Loss—Lbs.	
Gals. per Min.	4″ Pipe	6″ Pipe
200	1.22	0.17
300	2.66	0.37
400	4.73	0.65
500	7.43	0.96
600	10.60	1.43
700	14.40	1.91
800		2.51
900		3.17
1000		3.88

From the above, it can be readily seen that friction loss in standpipe can be practically disregarded, because for a 6-inch pipe 500 feet long the loss of pressure is less than 1 pound.

OTHER SOURCES OF FRICTION LOSS.

1. Loss of head due to entrance.
2. Loss of head due to bends and curves.
3. Loss of head due to changes in diameter.
4. Loss of head due to obstructions.
5. Loss of head due to siamese connections, outlet valves, check valves and fittings.

The following loss for friction should be allowed:

Siamese connections, 5 pounds pressure loss.
Swing check valve, 10 pounds pressure loss.
Outlet valve, 10 pounds pressure loss.

NOZZLE DISCHARGE.

The number of gallons of water discharged through any size nozzle per minute may be obtained by the following rule:

1st, multiply the diameter of the nozzle by itself.

2nd, multiply above product by 29.7 or 30.

3rd, then multiply the above result by the square root of the nozzle pressure.

The above rule may be expressed as follows:

$$\text{Gals. per min.} = 29.7 \times \text{dia.} \times \text{dia.} \times \sqrt{P}$$

$$\text{or } 29.7 \times d^2 \times \sqrt{P}$$

P=Pressure shown on gauge "A."

d=Diameter of nozzle in fractions of an inch as shown at "B."

29.7 or 30 is a constant determined by experiment.

Problem:—Given a nozzle 1¼ inches in diameter, pressure as shown on gauge, say, 64 pounds, what is the discharge in gallons per minute?

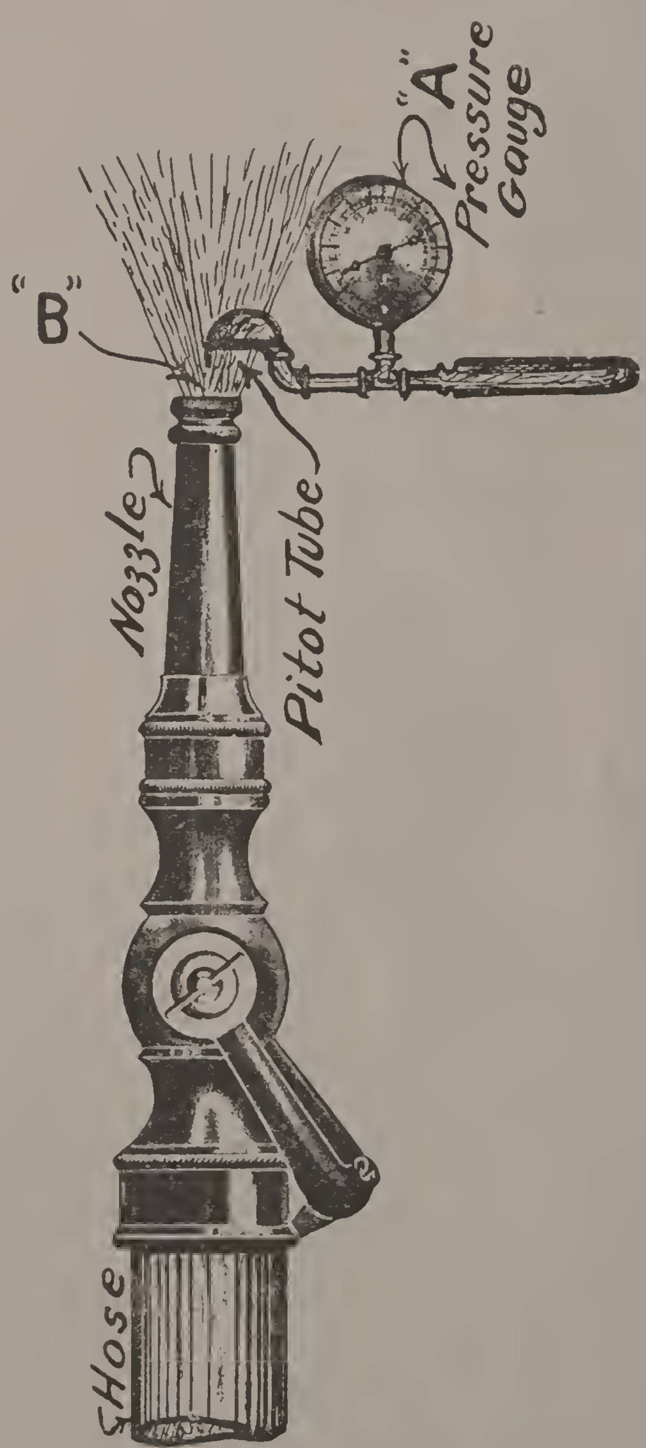
Answer:

From formula we have:

$$\text{Gals. per min.} = 29.7 \times 1.25 \times 1.25 \sqrt{64}$$

$$\text{or Gals. per min.} = 29.7 \times 1.25 \times 1.25 \times 8$$

Square root of 64=8.



Sketch Showing Method of Testing Nozzle Pressure.

```
Diameter  1.25
   "      1.25
          ----
           625
          250
         1 25
         -----
         1.5625=dia.×dia.
              8=√64
         -----
         12.5
         29.7=constant
         ----
          8 75
        112 5
        250
        ------
        371.25 gals. per min.
```

For cubic feet, divide 371.25 by 7.5.

For all practical purposes, 30 instead of 29.7 may be used as a constant, as this figure would be correct within 1 or 2 per cent.

NOZZLE AND ENGINE PRESSURES.

FORMULA FOR OBTAINING APPROXIMATE NOZZLE OR ENGINE PRESSURES, LENGTH OF LINE AND SIZE OF NOZZLE BEING GIVEN.

$$\text{Nozzle Pressure in pounds} = \frac{\text{Engine Pressure}}{1.1 + K\ L}$$

Engine Pressure in pounds = Nozzle Pressure $(1.1 + K\ L)$.

L = Number of 50-foot lengths of hose.

K = Constant, varying with size of nozzle and hose. See Table following.

Size Nozzle, Inches.	K FOR					
	Single Line 2½" Hose.	Single Line 3" Hose.	Single Line 3½" Hose.	Two 2½" Lines Siamesed. *	Two 3" Lines Siamesed. *	3 Lines 2½" Hose. *
1	.105	.038	....	025	....	....
1⅛	.167	.062	....	.043	....	...
1¼	.248	.092	.039	066	.023	.028
1⅜	.341	.137	.059	.096	.034	.043
1½	.505	.192	.084	.135	.051	.061
1⅝	.680	.266	.113	.184	.068	.084
1¾	.907	351	.152	.242	.093	.115
2	1.550	.605	.250	418	.157	190

* Allowance is made for loss in deluge set; these values will also give approximately correct figures for turret nozzles and water tower, except that in the latter, pressure equal to 0.434 times the height of tower must be subtracted from the engine pressure, before solving for nozzle pressure.

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PROBLEMS
in
Engine and Nozzle Pressures

1- What must be the Engine Press. necessary to maintain a nozzle press. of 55 pounds through a 1¼ inch nozzle attached to 200 feet of 2½" hose?

Ans.:

Using Formula we have

$$\text{Engine Press.} = 55 \times (1.1 + \overset{K}{.248} \times \overset{L}{4})$$

Note: .248 is given in table for 2½" hose & 1¼" Nozzle

$$4 = \frac{200}{50}$$

```
  .248 = K
     4 = L
  ----
   .992
+ 1.1
  -----
  2.092
```

```
     2.092
        55
    ------
    10460
   10460
   -------
   115.060 = Engine Pressure
```

Ans.

2- Given Engine Pressure of 115.06 Pounds and same conditions as in problem -1- to find Nozzle Pressure.

$$\text{Nozzle Pressure} = \frac{\text{Engine Press.}}{1.1 + K \times L}$$

$$= \frac{115.06}{1.1 + .248 \times 4}$$

$$= \frac{115.06}{2.092}$$

```
2.092)115.06(55 Ans.
      10460
      -----
       10460
       10460
       -----
```

WATER TOWER DISCHARGE.

Problem:—Find the nozzle pressure on a water tower 65 feet in height, using proper-sized nozzle where engine pressures are given, as follows: Three second-size engines using 3-inch hose from each one to water tower. Lengths of hose and pressure on engines as shown in sketch.

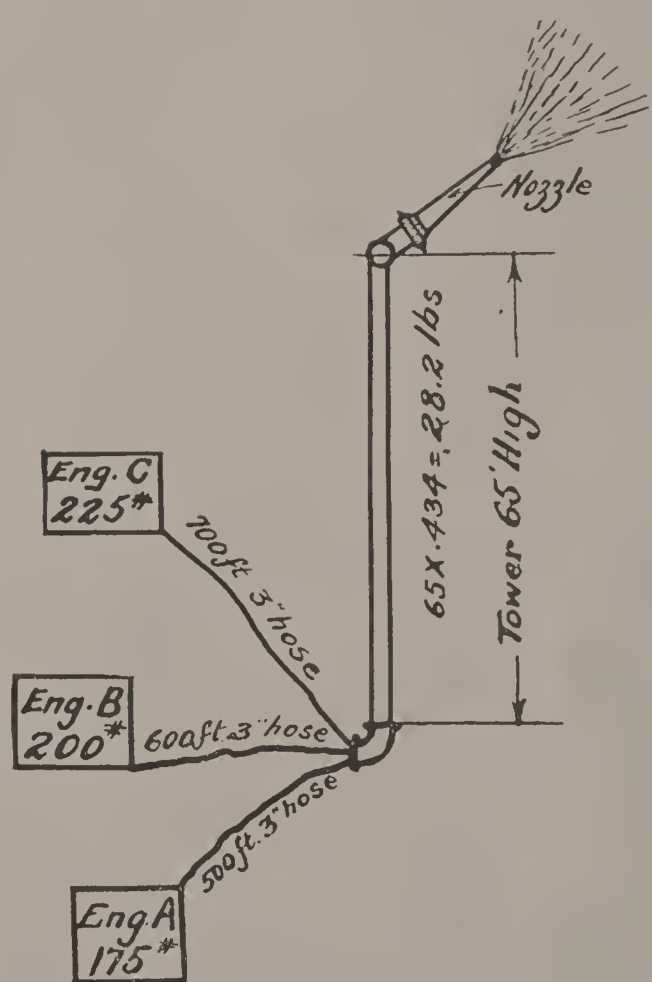
ANSWER:—In this problem candidates should be familiar with capacity of second-size engines, as one of two things must be assumed: either the discharge under the varying pressures, or else the discharge at the nozzle on the tower.

Under the pressures given, assume each engine capable of pumping 250 gallons each; this is a reasonable figure for second-sized steamers.

Take engine "B," and the pressure at base of water tower would equal 200 pounds, which is the engine pressure less 33 pounds friction loss in hose, or 200—33=167 pounds pressure at base of tower.

Friction loss in water tower, including standpipe and connections, equals about 10 pounds. Also the pressure due to 65 feet of height in the tower=65×.434=28.2 pounds. The net pressure at the tower nozzle is therefore 167—(10+28.2)=128.8 pounds. This is nozzle pressure which will discharge 700 gallons per minute.

Neglecting the friction in the nozzle, 1½-inch smooth nozzle, or 1¾-inch ring nozzle, will take care of this discharge.



NOTE:—Engine "B" is taken as an average between engines "A" and "C," and for examination purposes it illustrates an approximate method of finding the answer without going into a two or three-page calculation.

HEIGHT OF STREAMS.

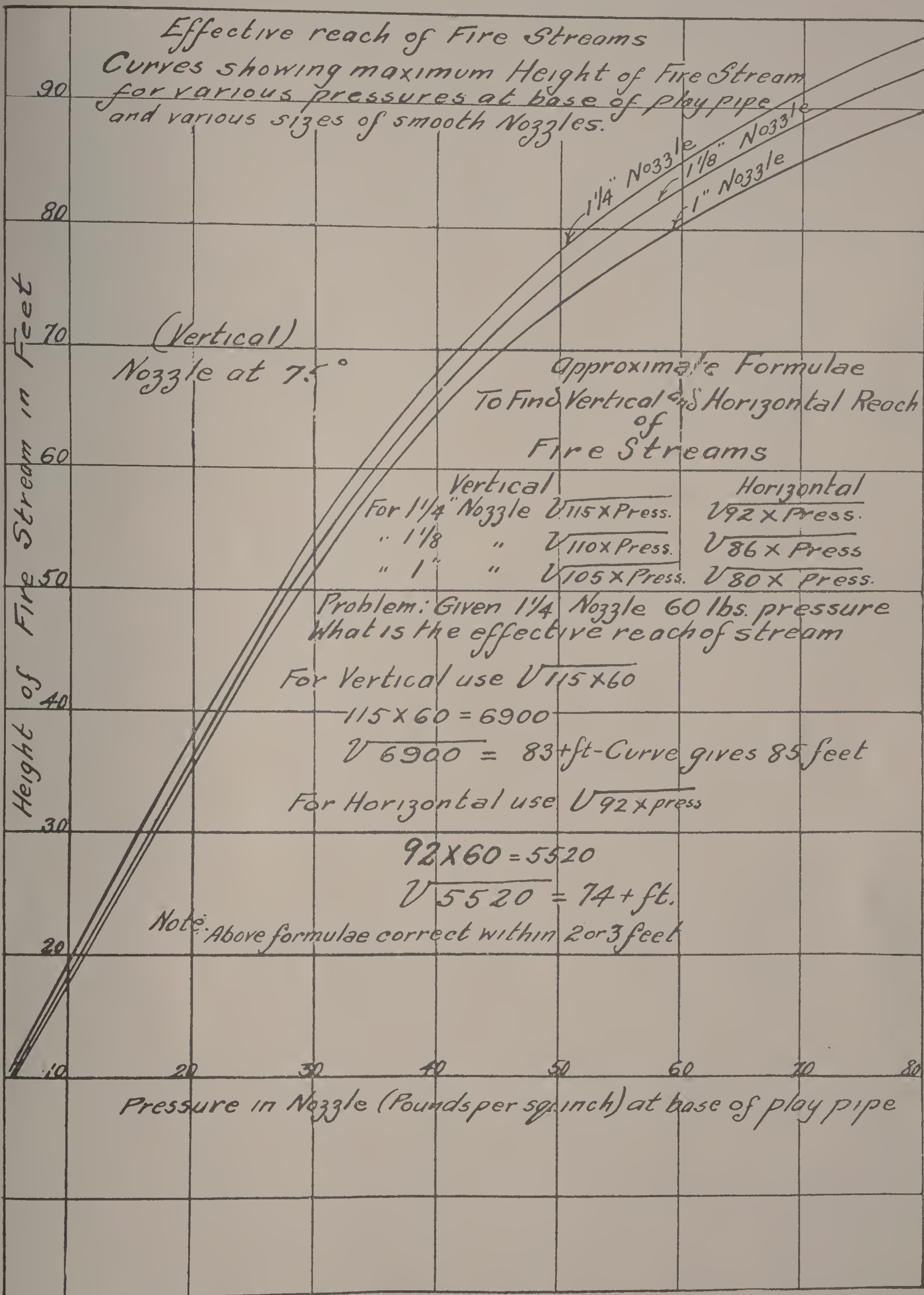
The height to which a stream of water can be thrown depends on the resistance of the air to the passage of the water, and the larger the diameter of the column of water is, the less is the area exposed to the air in proportion to the volume of water; therefore, the larger streams can be thrown to greater heights than smaller ones.

If there were no resistance of the air and no friction at the nozzle and in the connecting pipes, a stream of water would rise exactly to the height of the surface of the water in a tank supplying the stream, or it would seek its own level.

Now, a column of water 2 1/3 feet high will exert a pressure of one pound per square inch at the base of the column, so that to get the theoretical height of a column of water equivalent to 60 pounds pressure, we multiply $2\ 1/3 \times 60 = 140$ feet, the height of a column of water giving 60 pounds pressure per square inch, and also producing a stream which should, in the absence of retarding forces, reach a height of 140 feet.

Even with no wind blowing it has been found by experiment that the height to which a stream can be thrown falls far short of that calculated as above, at least where the pressures are considerable compared with the size of the nozzle, and on gradually increasing the pressure a maximum height for each sized nozzle is reached, beyond which further pressure reduces the height.

The accompanying curve diagram showing effective reach of fire streams, and rules for finding vertical and horizontal reach of fire streams, will greatly aid the candidate in solving problems which heretofore may have seemed very difficult.



(The above curves are from tests by Mr. J. R. Freeman, M. E.)

EFFECTIVE REACH OF FIRE STREAMS.

SHOWING THE DISTANCE IN FEET FROM THE NOZZLE AT WHICH STREAMS WILL DO EFFECTIVE WORK WITH A MODERATE WIND BLOWING. WITH A STRONG WIND THE REACH IS GREATLY REDUCED.

Pressure at Nozzle.	Size of Nozzle.									
	1-Inch.		$1\frac{1}{8}$-Inch		$1\frac{1}{4}$-Inch.		$1\frac{3}{8}$-Inch.		$1\frac{1}{2}$-Inch.	
	Vertical Distance, Feet.	Horizontal Distance, Feet.	Vertical Distance, Feet.	Horizontal Distance, Feet.	Vertical Distance, Feet.	Horizontal Distance, Feet.	Vertical Distance, Feet.	Horizontal Distance, Feet.	Vertical Distance, Feet.	Horizontal Distance, Feet.
20	35	37	36	38	36	39	36	40	37	42
25	43	42	44	44	45	46	45	47	46	49
30	51	47	52	50	52	52	53	54	54	56
35	58	51	59	54	59	58	60	59	62	62
40	64	55	65	59	65	62	66	64	69	66
45	69	58	70	63	70	66	72	68	74	71
50	73	61	75	66	75	69	77	72	79	75
55	76	64	79	69	80	72	81	75	83	78
60	79	67	83	72	84	75	85	77	87	80
65	82	70	86	75	87	78	88	79	90	82
70	85	72	88	77	90	80	91	82	92	84
75	87	74	90	79	92	82	93	84	94	86
80	89	76	92	81	94	84	95	86	96	88
85	91	78	94	83	96	87	97	88	98	90
90	92	80	96	85	98	89	99	90	100	91

NOTE.—Nozzle pressures are as indicated by Pitot tube. The horizontal and vertical distances are based on experiments by Mr. John R. Freeman, *Transactions*, Am. Soc. C. E., Vol. XXI.

(From "Fire Engine Tests and Fire Stream Tables," published by permission of the National Board of Fire Underwriters.—Copyrighted.)

Pump Slip and Pump Displacement

Displacement of a pump for a single stroke is the volume of water that would be displaced by the piston during that stroke.

Rule: To find the displacement of a pump in cubic ft. per minute, when the length of stroke, diameter of piston or plunger, and number of strokes per minute are given, multiply the length of stroke in feet, by the number of strokes per minute, and this product by the Area of the piston in square ft; then the final product equals the displacement.

To calculate the "Slip" of a pump find the difference between the displacement and the actual discharge. Then divide this difference by the displacement, and the result expressed as per cent will be the slip.

Problem: A pump has a plunger 8 inches in diameter, 36" Stroke, discharge 33.5 Cubic feet of water per minute, and has 35 discharging strokes. What is the "Slip"?

$$\text{Displecement} = \frac{.7854 \times 8^2}{144} \times 3 \times 35 = 36.65 \text{ cubic feet per minute}$$

$$\text{Slip equals } \frac{36.65 - 33.5}{36.65} = .086 = 8.6\% \text{ Ans.}$$

```
 .7854
    64 = 8²
 -----
 31416
47124
-------
50.2656
    105 = 3x35
-------
 2513280
5026560
---------
5277.8880
```

Sq. inches in one sq. foot

```
144)5277.880(36.65+
    432
    ---
     958
     864
     ---
      948
      864
      ---
       848
       720
       ---
       128
```

```
                    36.65 - Displacement
                    33.50 - Discharge
                    -----
Displacement-36.65) 3.1500 (.086
                    29320
                    -----
                     21800
                     21990
                     -----
```

Pump Capacity

Rule:

(1) Square the diameter of Pump cylinder
(2) Multiply (1) by travel of Piston in inches per revolution
(3) " (2) by the constant .0034

The above gives the displacement of pump in gallons per revolution, but does not include the displacement of plunger rod, which must be deducted to get net displacement.

To find displacement of plunger rod:

Rule:

(1) Square the diameter of Plunger Rod
(2) Multiply (1) by travel of piston for 1/2 revolution
(3) " (2) by constant .0034

Problem:

What is the capacity of a pump having a 5" cylinder, Stroke 8," Plunger Rod $1\frac{1}{2}$" dia., making 300 Rev. per min.

5X5=25
8X2= 16 inches travel for 1 Rev.
25X16 = 400 cubic inches
400 x .0034 = 1.36 gallons capacity per rev. less disp. of plunger rod

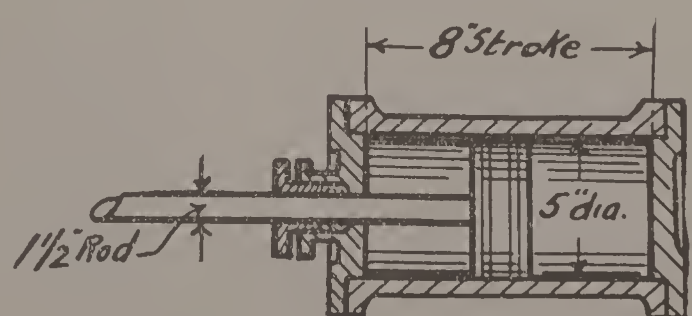
$$\begin{array}{r} .0034 \\ \underline{400} \\ 1.3600 \end{array}$$

Plunger Rod

1.5 x 1.5 = 2.25 X 8 = 18
18X.0034 = .0612 disp. in gals. of plunger rod.
1.36 less .0612 = 1.2988
1.2988 X 300 = 390 Gals.

$$\begin{array}{r} .0034 \\ \underline{18} \\ 272 \\ \underline{34} \\ .0612 \end{array}$$

$$\begin{array}{r} 1.3600 \\ \underline{.0612} \\ 1.2988 \\ \underline{300} \\ 389.6400 \end{array}$$ Say 390



Note:

Constant .0034 equals

$$231 \overline{)\,.7854}\ \underline{|.0034}$$
$$\begin{array}{r} 693 \\ \hline 924 \\ 924 \end{array}$$

231 = Cubic inches in one gallon

Horsepower of a Fire Engine

Rule: Multiply the area of the piston by the Steam pressure in pounds per square inch; then multiply this result by the travel of the piston in feet per minute; divide this result by 33000, and .7 of this will be the "Horsepower."

Problem: What would be the H.P. of a Fire Engine with cylinders 9 inches diameter, 90 lbs. steam pressure, stroke 9 inches, and making 200 revolutions per minute?

Solution:

9 X 9 X .7854 = Area of Piston in square inches = 63.6
63.6 X 90 = " " " multiplied by pres. = 5725.6
9 X 2 = 18" = 1½ ft = Travel of Piston in 1 Revolution
1½ X 200 = 300 ft. = " " " " 1 minute
5725.6 X 300 = 1,717,669.8

$$\frac{1{,}717{,}669.8}{33000} = 52.05 \times .7 = 36.4 \text{ H.P. Ans.}$$

.7854
9X9 = 81
7854
62832
63.6174
90
5725.5660
300
1,717,669.8000

33000)1,717,669.80(52.05
165000
67669
66000
166980
165000

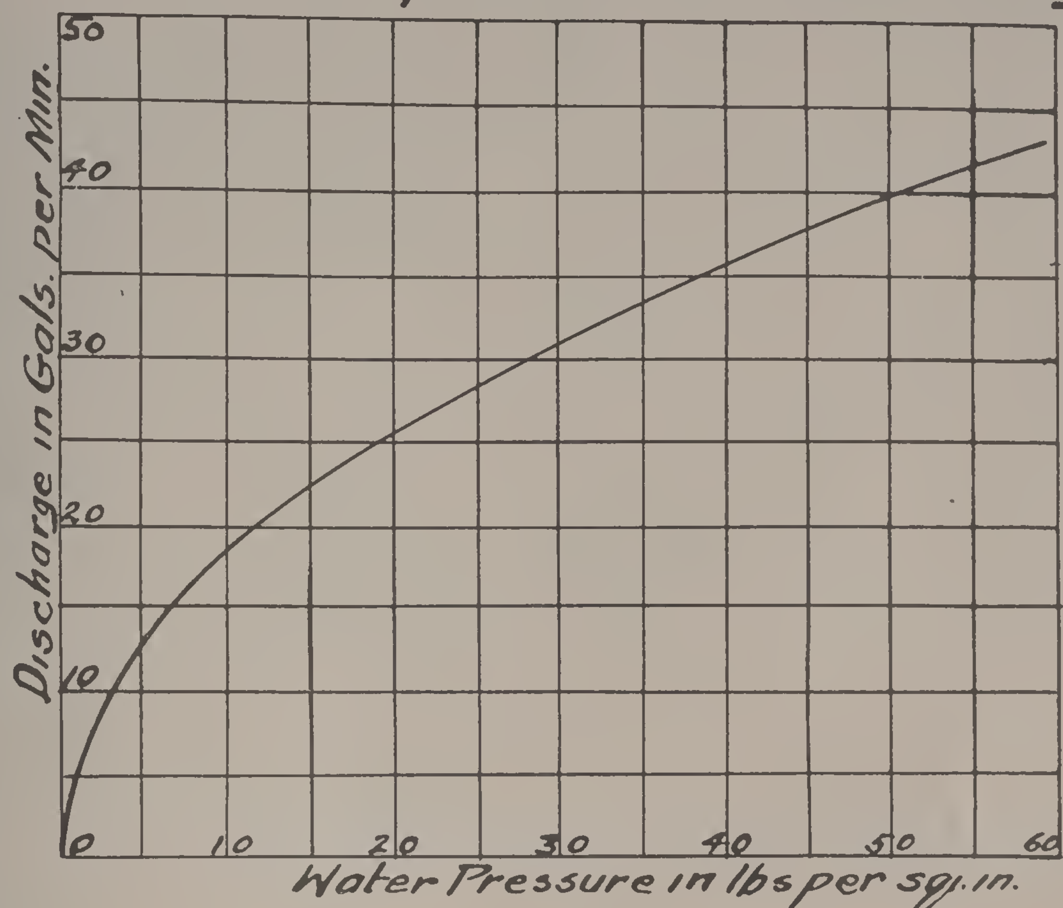
52.05
.7
36.435 = Horse Power

RATED CAPACITIES OF STEAM FIRE ENGINE.

The rated capacities of steam fire engines which are perhaps one-third greater than their ordinary rate of work under the heavier pressures are as follows:

3rd size:	550 gals. per min., or	792,000 gals. per 24 hours.
2nd size:	700 gals. per min., or	1,008,000 gals. per 24 hours.
1st size:	900 gals. per min., or	1,296,000 gals. per 24 hours.
Extra 1st size:	1,100 gals. per min., or	1,584,000 gals. per 24 hours.
Double extra 1st size:	1,200 gals. per min., or	1,728,000 gals. per 24 hours.

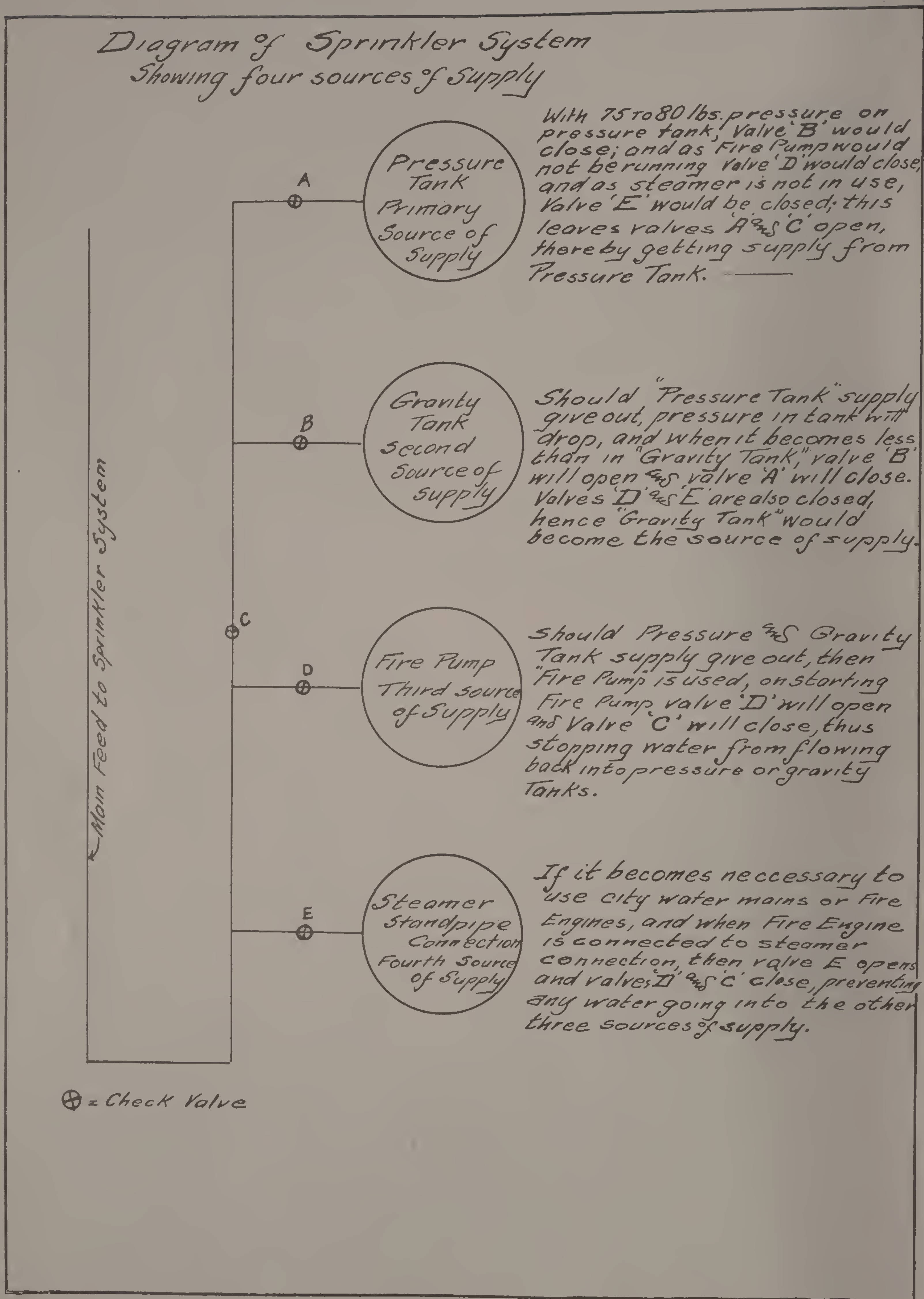
Automatic Sprinkler Discharge



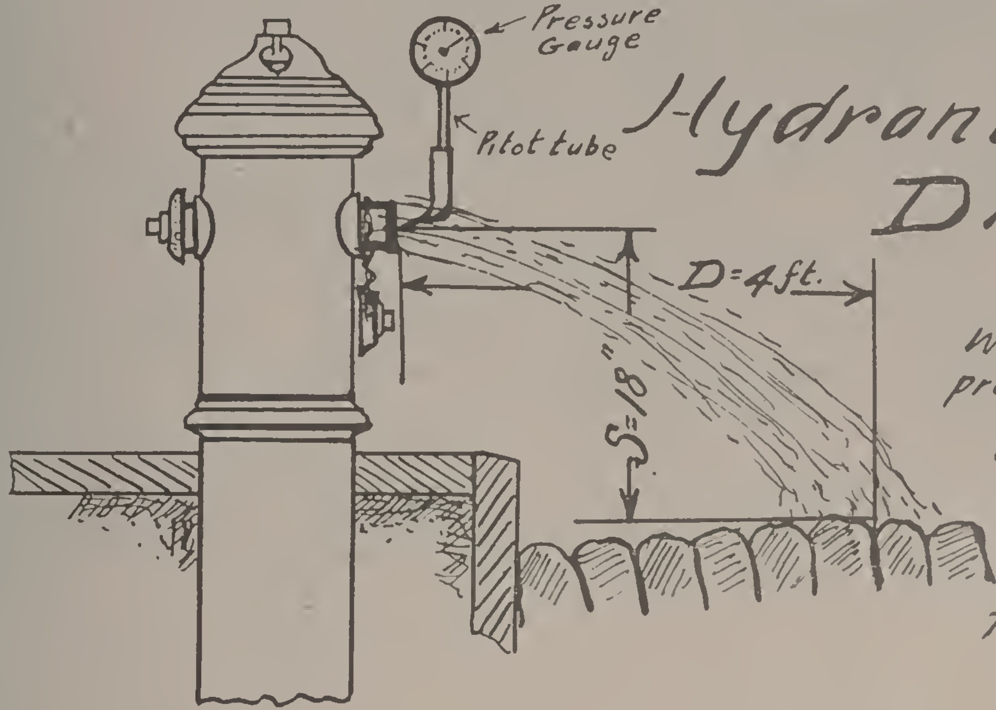
The rate at which an automatic sprinkler discharges water after being opened by fusing of the Solder, is dependent upon the water pressure to which it is subjected. The above curve shows the relation between water pressure, and rates of dilivery of a modern sprinkler.

Sprinklers may be considered fairly effective as fire extinguishing agents when discharging water under a pressure of 15 lbs. per square inch at the nozzle, if spaced over a ceiling in accordance with standard practice, but somewhat higher pressures are preferred and are available in a majority of sprinklered buildings.

(Acknowledgment is made to Mr. Fitzhugh Taylor for the above table.)



(From "Notes on Hydraulics," by the Insurance Press.)



Hydrant Discharge

When pitot tube & press. Gauge are used

$V=\sqrt{2gh}$ $Q=A.V.$

h = head in feet

Say Gauge Press. = 24

Then "h" $= \frac{24}{.434} = 55$ ft

Problem: (No pressure gauge used)
What would be the discharge in Gallons per min. from a Hydrant which throws a stream of 4 feet through a 4 inch outlet? The center of outlet is 18 inches from cobble stone. (see Sketch)

Formulas — $Q = A \times V$ and $V = D\sqrt{\frac{g}{2S}}$

Let D = Distance of Stream from Hydrant (4 feet)
" S = " from ℄ of outlet to Cobblestone = (1½ feet)
" V = Velocity in feet per second
Q = Quantity in cubic ft per second
g = gravity = 32.16 feet " "
A = Area of outlet in square feet

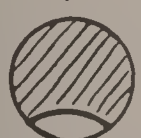
Area of 4" outlet $= \frac{4 \times 4 \times .7854}{144} = .0872$ sq. feet

$$V = D\sqrt{\frac{g}{2S}} = 4\sqrt{\frac{32.16}{2 \times 1\frac{1}{2}}} = \sqrt{\frac{32.16}{3}} = \sqrt{10.72} = 3.3$$

$4 \times 3.3 = 13.2$ feet (velocity)

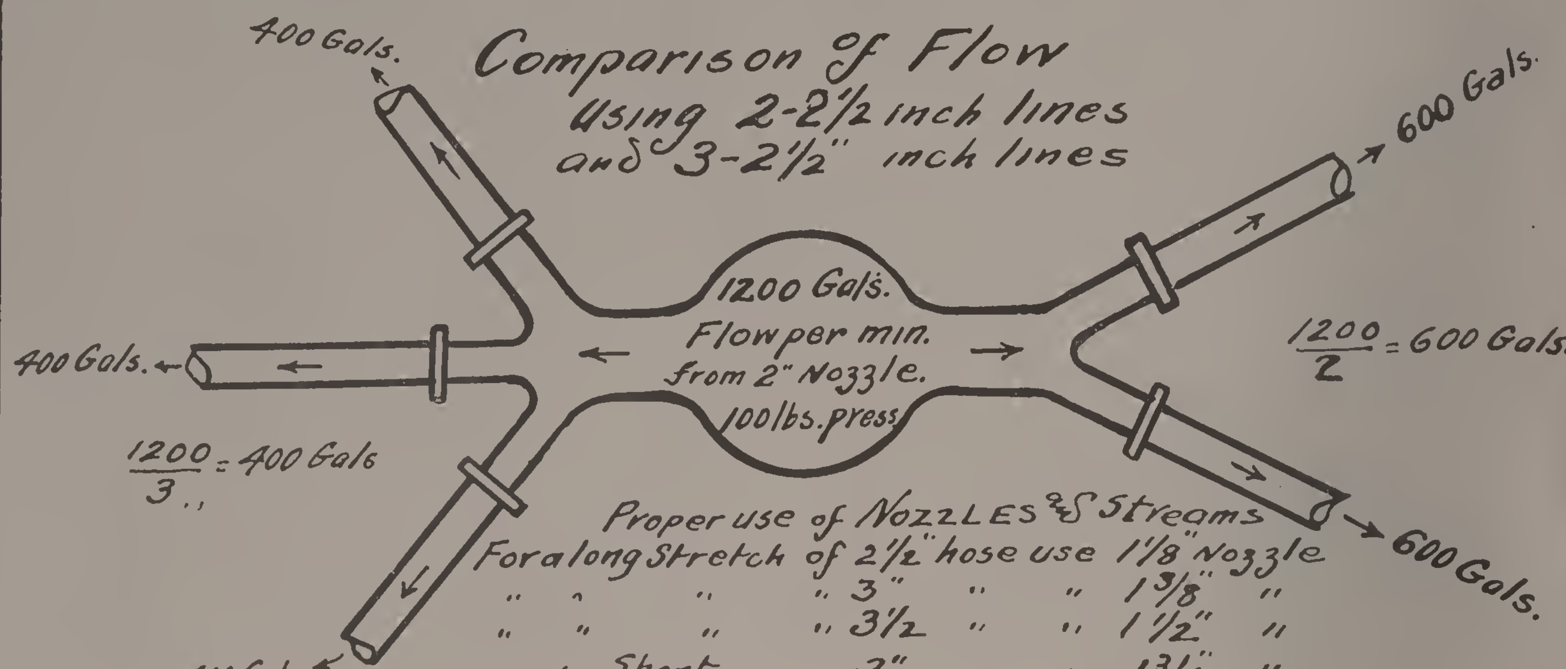
Now – $Q = AV = .0872 \times 13.2 = 1.151$ cubic ft. per second

$1.151 \times \underset{(sec.)}{60} \times \underset{(Gals.)}{7.5} = 517.5$ Gals. per minute (Say 520)



Use about 80% of discharge as shown by shaded circle, this will give the actual effective area.

Ans = $.80 \times 520 = 416$ Gals. per min



Proper use of NOZZLES & Streams

For a long Stretch	of 2½" hose	use	1⅛" Nozzle	
" "	"	3"	" "	1⅜" "
" "	"	3½	" "	1½" "
" " Short	"	3"	" "	1¾ "
" " Medium	"	3"	" "	1½ "

Problem:

Assume a nozzle pressure of 100 lbs. from a 2 inch nozzle, giving a discharge of 1200 Gallons per minute. Show a comparison of "Friction Losses" when using two 2½ inch lines and when using 3-2½" lines.

Note: For same size pipes, same length and same roughness of surface, the friction varies as the square of the velocity or V^2. Velocity is governed by flow. Hence:

$400 \times 400 = 160000$

$600 \times 600 = 360000$

or friction is $\frac{160000}{360000}$ or 16 to 36 or 2¼ times

That is, the friction when using two 2½" lines is 2¼ times greater than when using three 2½" Lines.

When forcing 1200 Gallons per minute through 2 Lines, the pressure must be greater than if the same quantity were forced through 3 Lines, in order to get the same nozzle pressure. The additional line gives a better flow, less friction, and greater nozzle velocity.

CIVIL SERVICE EXAMINATION PROBLEMS.

Problem:—With 200 feet of 3-inch hose to standpipe and 50 feet of $2\frac{1}{2}$-inch hose on the sixth floor, what should be the water pressure at the engine if the discharge pressure at the $1\frac{1}{8}$-inch nozzle is 30 pounds?

ANS.:—A $1\frac{1}{8}$-inch nozzle with 30 pounds at the nozzle would discharge: Gals. per min. $=29.7\times1\frac{1}{8}\times1\frac{1}{8}\times\sqrt{30}=205$, or approximately 205 gallons per minute, and with the following friction loss:

On 200-ft. 3-in. hose, 200 gals. flow $=\frac{\overset{200}{2}}{4}\times2=$	8 lbs.
On standpipe to 6th floor $=6\times12=72\times.434=$	31 lbs.
On 50-ft. $2\frac{1}{2}$-in. hose, 200 gals. flow $=\frac{2\times2\times2+2}{2}=\frac{10}{2}=$....	5 lbs.
Outlet valve	10 lbs.
On siamese connection, etc.	5 lbs.
Swing check valve	10 lbs.
On nozzle pressure	30 lbs.
	99 lbs.

Water pressure at engine should be approximately 99 pounds. This is allowing 12 feet per story.

Problem:—(a) What effect has the length of the line of hose upon the pressure at the nozzle?

(b) Show by arithmetic how much more water is necessary to supply a $1\frac{1}{2}$-inch nozzle than a 1-inch nozzle at the same pressure.

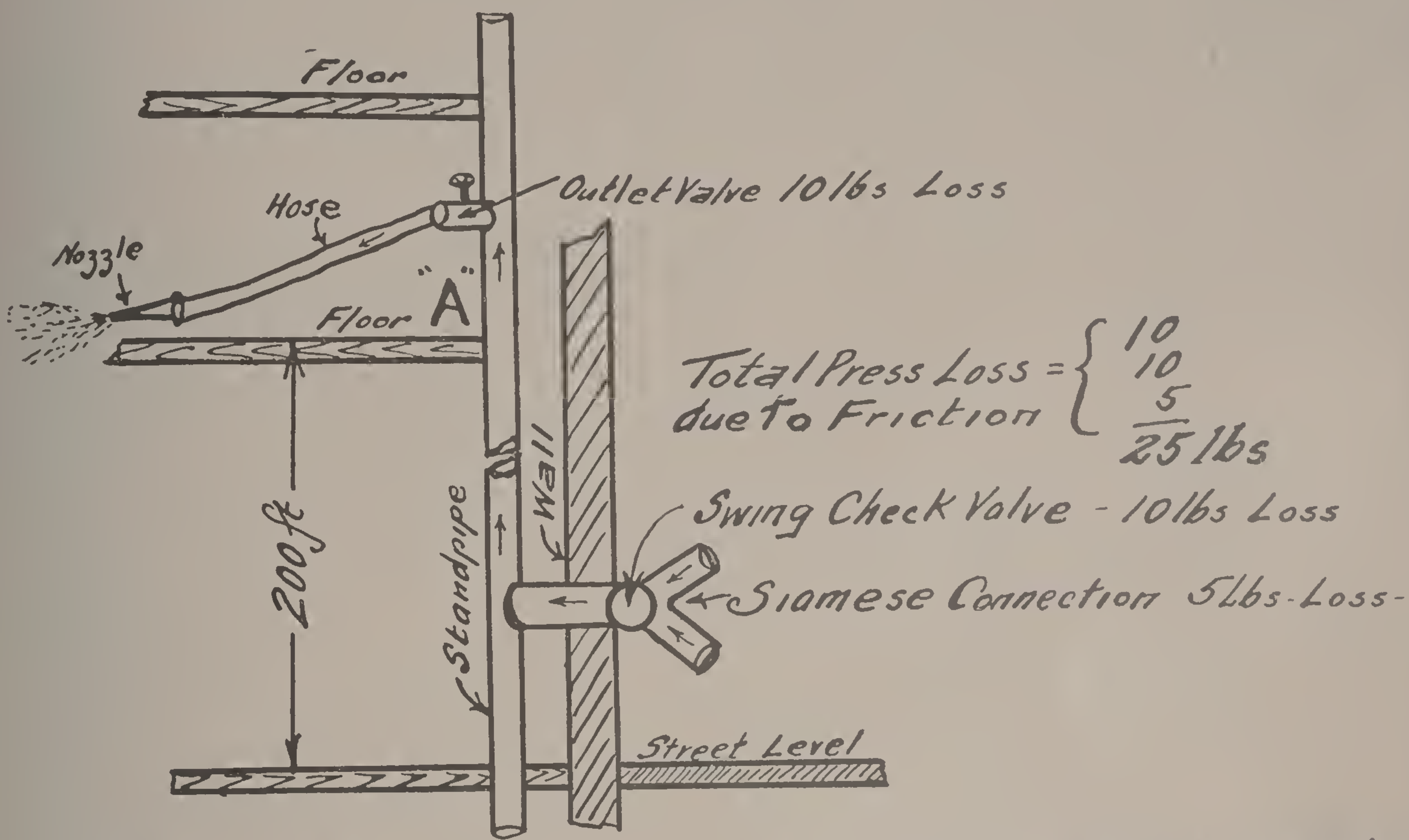
ANS.:—(a) It is very important to have the proper-sized nozzle on the line to secure an effective stream. If the nozzle is too small, the water will choke at the tip, causing it to spray. If the nozzle is too large, the stream will not be effective. Therefore, to obtain the best results, change the nozzle to suit the various pressures.

As friction loss is proportional to the length of hose, the length of the hose makes a great difference in the quantity of water delivered in a given time, for when the hose is very long considerable pressure is lost through the friction of the water passing through the hose. The speed at which the engine works depends very much on the length of the suction hose, the length of the delivery hose and the size of the nozzle. These determine the amount of water that can be delivered by the pump or discharged from it.

(b) This varies as the square of the diameter, or:

1.5-inch nozzle	1-inch nozzle
1.5	1
75	1
15	
2.25	
1.	
1.25 times more water. (Ans.)	

Standpipe



To obtain pressure required to deliver water at any floor in a standpipe: Find height of floor as shown (200 ft) from ground, allow 12 feet for each story. Multiply height by .434 and add 25 lbs for Friction (See Sketch)

Problem: What pressure is required to deliver water to floor "A" which is 200 ft from ground?

$$
\begin{aligned}
200 \times .434 &= 86.8 \text{ lbs} \\
\text{add } & \underline{25.0} \text{ for Friction} \\
& 111.8 \text{ Say - 112 lbs}
\end{aligned}
$$

112 lbs required to deliver water to floor "A".

To this 112 lbs add the nozzle pressure, and the result is Engine press. required.

Problem:—(a) What would be the pressure loss in 10 lengths of 3-inch hose when flow is 300 gallons per minute?

(b) With 50 pounds pressure at a $1\frac{1}{8}$-inch nozzle, what would be the horizontal and the vertical reach of the stream?

ANS.:—(a) Pressure loss is as follows:

300	gallons flow
3	
9	loss for 100 feet of hose
5	
45	loss for 500 feet of hose.

(b)

Vertical Stream.		*Horizontal Stream.*	
For $1\frac{1}{8}$ nozzle $=\sqrt{110\times\text{pressure}}$		For $1\frac{1}{8}$ nozzle $=\sqrt{86\times\text{pressure}}$	
Pressure given as 50 lbs.		Pressure given as 50 lbs.	
110	5500 (74 feet	86	4300 (65 feet
50	49	50	36
5500	144) 600	4300	125) 700
	576		625
	24		75

Problem:—In answering the following, show the methods used in arriving at the answer given:

There is a large fire in a building 100 feet high from the curb to the cornice. The sidewalk is 10 feet wide and the street from curb to curb is 30 feet wide. A pipeholder is placed against the curb on the opposite side from the fire. You are required to deliver an effective stream of water to the top floor. You are using 300 feet of 3-inch hose with a $1\frac{1}{2}$-inch nozzle. What is the approximate distance from the nozzle at the curb to the top story windows, allowing 10 feet to a story; what pressure would you require on the nozzle; how many gallons of water would the nozzle discharge per minute, and what would be the required pressure on the engine or hydrant to maintain this discharge?

ANS.:—The approximate distance from the nozzle at the curb to the top story windows, allowing 10 feet to a story, is obtained by adding the curb and street widths, which are 10+30, or 40 feet, and multiplying this by itself, which gives 1,600. Then deduct at least 5 feet from the building height, as the stream is supposed to enter the window, and the nozzle is also several feet off the sidewalk. This gives 100—5 which equals 95 feet.

Multiply this by itself, giving 9,025. Add the 1,600 to it, which makes 10,625. Get the square root of 10,625, which equals about 103 feet.

```
 40×40=1,600              √1′06′25(103=square root
 95×95=9,025                1
      ——————              ————
      10,625         203)  0625
                            609
                           ————
                             16
```

As nozzle pressure, engine pressure and gallons per minute are wanted, assume one to find the others.

Assume 93 pounds nozzle pressure. Then:

Gals. per minute $=1\frac{1}{2}\times1\frac{1}{2}\times\sqrt{P}\times29.7$

```
      ————
  √    93   (9.64=square root of 93 lbs. nozzle pressure
       81
      ————
  186)1200
      1116
      —————
  1924)8400
       7696
       ————

        1.5
        1.5=dia. of nozzle
       ————
         75
        15
       ————
       2.25=dia.×dia.
       9.64=square root of 93
       ————
        900
      1350
     2025
   ——————————
    21.6900
     29.7    =constant
   ——————————
     15183
    19521
    4338
   ——————————
   644.193  =644 gallons per minute.
```

Now, engine pressure=nozzle pressure×(1.1+K×L).
Nozzle pressure=93 pounds.
K=.192 for $1\frac{1}{2}$-inch nozzle 3-inch hose (see Underwriters' Table).
L=6=number of lengths of 3-inch hose.
1.1=constant given in formula.

Hence:

```
   .192=K
      6=L
  ------
  1.152
 +1.1   =constant
  ------
  2.252
     93=nozzle pressure
  ------
   6756
 20268
 -------
209.436 lbs. engine pressure.   (Say 209 lbs.)
```

Problem:—You respond to an alarm of fire and you find the fire is located on the sixth floor of a 20-story building. You go to work from the standpipe stretching two lines. You use one length of hose in each line and $1\frac{1}{8}$-inch nozzle. You work 45 minutes. How many gallons of water did you use?

There is a tank on the roof containing 20,000 gallons of water, to which the standpipe (6-inch) is connected. You may assume that the stories are 12 feet high. In answering this problem please give the work, and if any standard rules or measurements are given, please explain them.

Ans.:—The building is 240 feet high. The height from the street to the sixth floor is 60 feet. The height from the sixth floor to the roof is 180 feet.

```
Multiply 180 feet
          by .434
          ------
             720
            540
           720
          ------
          78.120=amount of lbs. pressure
          14 lbs. deducted for friction on 2 lengths of hose
          ------
          64.120 lbs. nozzle pressure.
```

To find the number of gallons used, multiply the square of the nozzle by the square root of the pressure, and then multiply the result by 29.7.

The square of the 1⅛-inch nozzle is 1.265.

```
     1.265
         8  square root of N. P.
    ------
    10.120
      29.7
    ------
     70840
    91080
   20240
    ------
  300.5640  gallons in one minute
        45  minutes
  --------
  15028200
 12022560
  --------
13525.3800  number of gals. used in 45 minutes.   (Ans.)
```

Problem:—There is a fire in a building which is 314 feet high and has a 15,000-gallon water tank on the roof. What pressure would be obtained on the sixth floor from the standpipe with two lengths of 2½-inch hose and 1⅛-inch nozzle, allowing 12½ feet to each floor?

Ans.:—The building being 314 feet in height, with a tank on the roof containing 15,000 gallons of water, and as the tank is supposed to be about 20 feet above the highest outlet, figuring 12½ feet per story, it would be approximately 262½ feet from the tank to the sixth floor outlet. You would receive approximately 114 pounds pressure, but must deduct 28 pounds for friction loss for a flow of 347 gallons of water, which gives you 86 pounds pressure at the nozzle.

From sixth floor to tank on roof is 21 stories.

```
   21
   12.5
  -----
   105
   42
  21
  -----
  262.5  feet
```

```
144)62.500(.434
     576
     ---
      490
      432
      ---
       580
       576
```

.434 is the weight of one square inch of water one foot high, and a cubic foot of water weighs 62½ pounds.

```
      .434
     262.5
   -------
    2170
    868
  2604
  868
  --------
  113.9250 lbs. gravity pressure on sixth floor outlet
   28.0000
  --------
   85.9250 say 86 pounds nozzle pressure.
```

From previous rules, friction loss on two lengths of 2½-inch hose would be about 28 pounds, and with a nozzle pressure of 86 pounds would be discharging approximately 347 gallons of water per minute.

Problem:—There is a fire on the 12th floor of a building, and it is to be extinguished by an engine at a hydrant 250 feet away, from which 300 feet of 3-inch hose is stretched to the standpipe, and from the standpipe outlet on the 12th floor there is stretched 100 feet of 2½-inch hose, on which is a 1¼-inch controlling nozzle, having a pressure of 81 pounds at the nozzle. What would be the pressure required at the engine?

Ans.:—Answering this question according to the official formula as per paragraph No. 1, Special Order No. 226, of December 14, 1915:

As the flow or discharge controls the friction loss, the flow must be ascertained as follows:

1.25×1.25=1.56+, diameter of nozzle by itself.
1.56×30=46.8 (then by constant 30).

Then multiply the above product by the square root of the pressure, which is 46.8×9=421+, number of gallons being discharged.

Friction loss in 100 feet of 2½-inch hose, as follows: For the first 200 gallons there is a loss of 10 pounds, and for each 10 gallons over 200 (or 421—200=221, or 22×10). There shall be added 1 1/3 pounds to the 10; hence 22×1 1/3=29 1/3 pounds, plus the 10 for the first 200 gallons equals 39 1/3 pounds friction loss.

Friction loss in standpipe as per N. Y. Fire College: For entry into siamese connection 5 pounds; for passing through the check valve 10 pounds, and for passing through the outlet valve 10 pounds, making a total of 25 pounds.

For elevation or head pressure as per N. Y. Fire College: Stories in New York are reckoned at 12½ feet, so 12 stories would be 12×12.5, or 150 feet. For each foot in elevation there is a head pressure or weight of .434 pounds; hence for 150 feet there would be $150 \times .434 = 65$ pounds plus.

Friction loss in the 300 feet of 3-inch hose, as follows: For the first 400 gallons there is a loss of 14 pounds, and for each 10 gallons over 400 (or $421 - 400 = 21$, or 2×10). There shall be added 4/5ths of a pound to the 14; hence $2 \times 4/5 = 1\ 3/5$ pounds, plus 14 for the first 400 gallons, equals 15 3/5 pounds for each 100 feet, and for 300 feet there is $3 \times 15\ 3/5$, equals 47 pounds (minus).

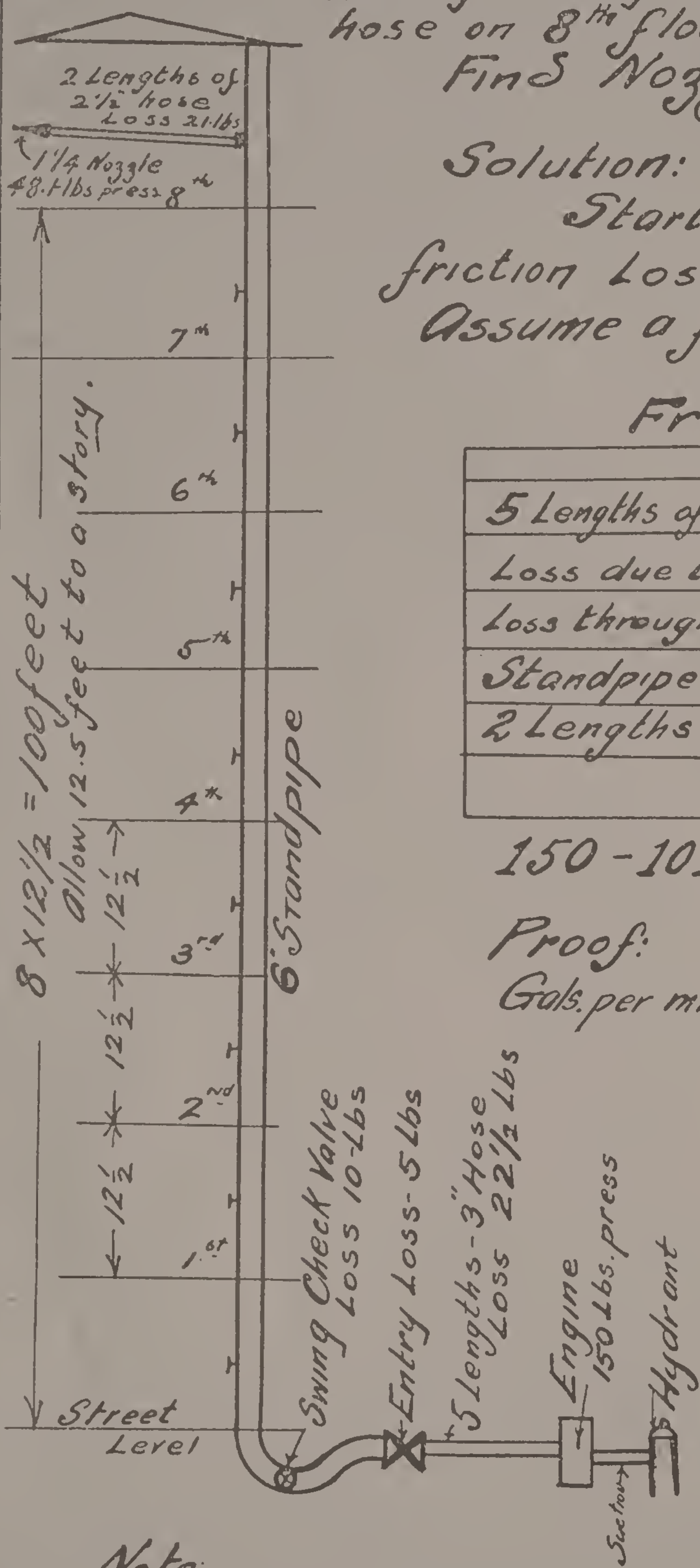
Therefore the pressure necessary at the engine would be the sum of the nozzle pressure, plus the loss in the 100 feet of 2½-inch hose, plus the friction loss in the standpipe, plus the weight of head pressure for the elevation, plus the friction loss in the 300 feet of 3-inch hose, as follows:

$81 + 39\ 1/3 + 25 + 65 + 47 = 257\ 1/3$ pounds, the pressure which would be necessary at the engine.

Problem:-

Given 150 lbs. Engine Pressure - 5 Lengths of 3" hose from engine to standpipe, 2 Lengths of 2½" hose on 8th floor - 1¼ inch nozzle,

Find Nozzle Pressure



Solution:

Start from engine and find friction Losses through Hose, Valves etc. Assume a flow of 320 Gals per min.

Friction Losses

	LBS.	
5 Lengths of 3" hose = 5 X 4½ =	22.5	
Loss due to Entry =	5.0	
Loss through Swing Check Valve =	10.0	
Standpipe = 100 X .434 =	43.4	
2 Lengths 2½" hose =	21.0	
Total Loss = 101.9 Lbs.		

150 - 101.9 = 48.1 Lbs Nozzle Pressure

Proof:

Gals. per min. = $29.7 \times 1.25 \times 1.25 \times \sqrt{P}$

$= 29.7 \times 1.25 \times 1.25 \times 7$ $\qquad \sqrt{48.1} = 7$ about

$$\begin{array}{r} 1.25 \\ 1.25 \\ \hline 625 \\ 250 \\ 125 \\ \hline 1.5625 \\ 7 \\ \hline 10.9375 \end{array} \qquad \begin{array}{r} 29.7 \\ 10.9 \\ \hline 2673 \\ 2970 \\ \hline 323.73 \end{array}$$

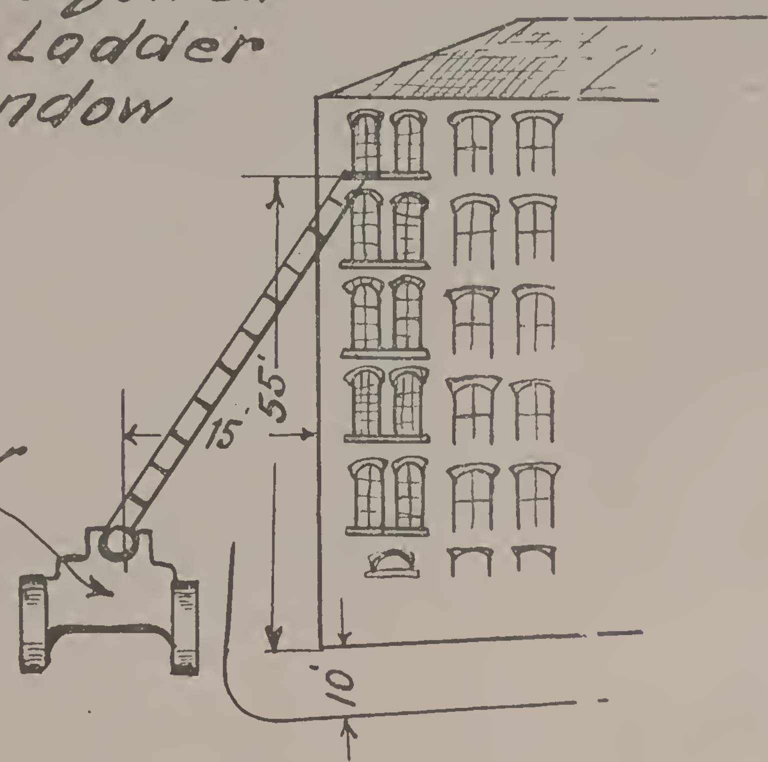
323.73 Gals per min

This checks assumed flow of 320 Gals, approximately

Note

Friction due to flow in standpipe is very small and has been omitted in this problem.

Distance Required to raise Fly Ladder to reach window



Note:

Proper distance to place truck from building is 15 feet

Problem:

From bottom of window sill to street level is 55 feet, sidewalk is 10 feet wide, bed of Ladder is 42 feet from ground. Find distance necessary to raise fly Ladder to window

Square the height the window is from street, allowing an extra foot for ladder to extend in window.

(1) Then 56 = 55+1

$$\begin{array}{r} 56 \\ \underline{56} \\ 3136 \end{array}$$

Square the distance the truck is from the building.

(2) Then

$$\begin{array}{r} 15 \\ \underline{15} \\ 225 \end{array}$$

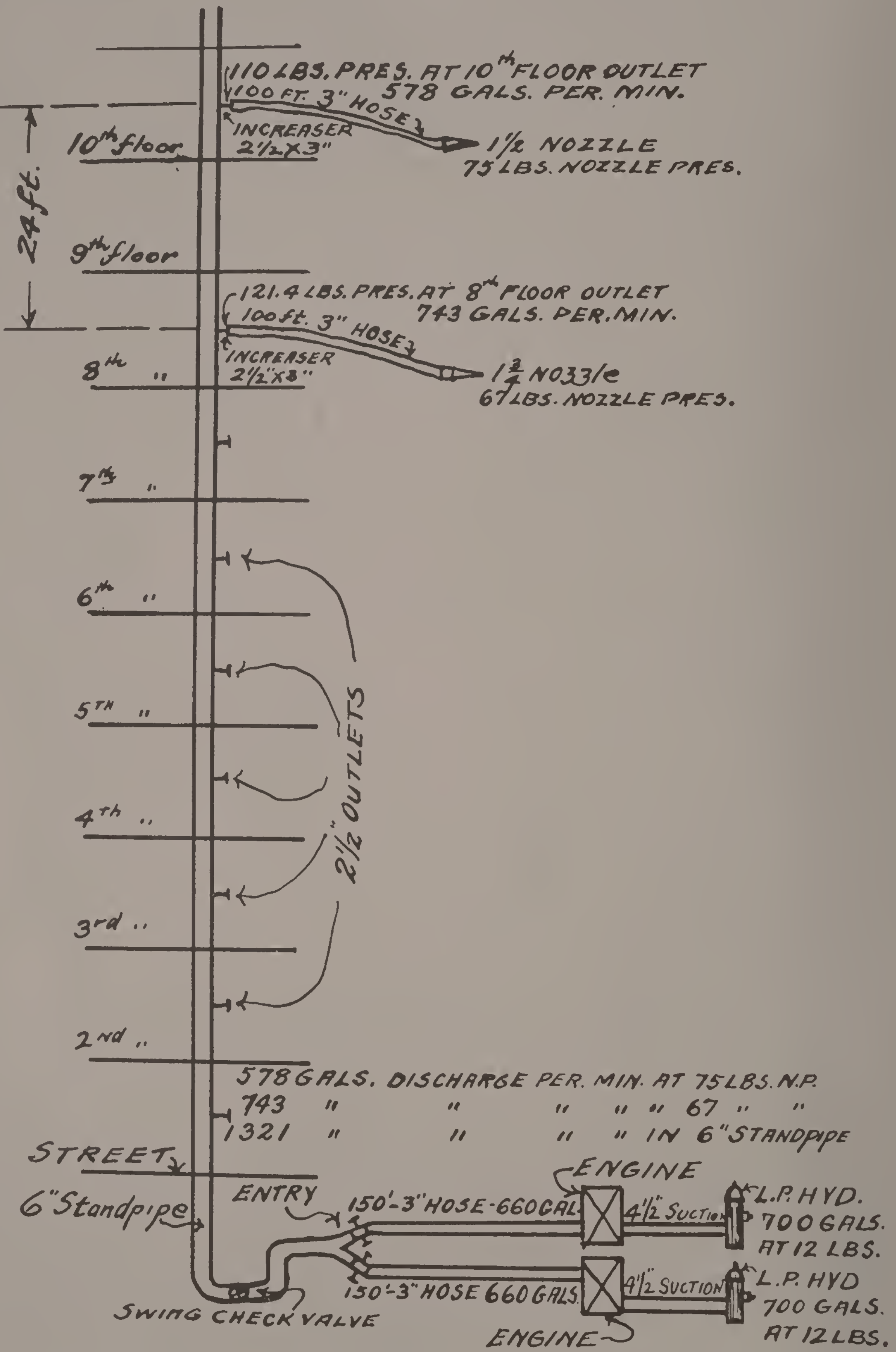
add (1) and (2) = 3136+225 = 3361

Take square root of 3361

$$\sqrt{3361} \;\; 58 \text{ approximate}$$

$$\begin{array}{rr} & 25 \\ \underline{108} & 861 \\ & \underline{864} \end{array}$$

Subtract 42 from 58 = 16 feet. Ans.



SKETCH SHOWING FRICTION LOSS FROM ENGINE TO NOZZLE

Problem:—It is desired to use across a 60-foot street a 1½-inch stream and a 1¾-inch stream from a building having a 6-inch standpipe located so that it will require 100-foot hose lines to reach each window.

One stream is to be located on the 8th floor and the other stream is to be located on the 10th floor. The streams are to be supplied from steam fire engines. Assume that any of the hydrants you might use are 150 feet from the standpipe and each with a supply pipe of 700 gallons per minute at 12 pounds.

(*a*) *What equipment would you require?*

(*b*) *On which floor would you locate the 1½-inch nozzle, the 1¾-inch nozzle?*

(*c*) *What pressure would you carry at each nozzle, and how much water would each nozzle discharge?*

(*d*) *Determine the pressure required at the engine.*

ANS.:—(a) *Equipment:*

6 lengths 3-inch hose in each line from engine to outside siamese connection.

1½-inch and 1¾-inch smooth bore open nozzles.

4 lengths of 3-inch hose, 2 lengths on the 10th floor, and 2 lengths on the 8th floor.

2 Perfection pipeholders, one taken to 8th and one to the 10th floor.

2 increasers, size 2½ by 3 inches, taken to 8th and 10th floors and connected to standpipe outlets.

Hose spanners for the purpose of making all connections perfectly tight.

(b) *Location of nozzles:*

The 1½-inch nozzle to be placed on 10th floor, and the 1¾-inch nozzle on the 8th floor.

(c) *Pressure at each nozzle:*

1½-inch nozzle=75 pounds nozzle pressure.

1¾-inch nozzle=67 pounds nozzle pressure.

Gallons of water discharged per minute through each nozzle:

1½-inch nozzle=1.5×1.5=2.25 square of nozzle×29.7 constant=66.825×square root of 75 pounds nozzle pressure=578 gallons.

1¾-inch nozzle=1.75×1.75=3.0625 square of nozzle×29.7 constant =90.8564 square root of 67 pounds nozzle pressure=743 gallons.

(d) .192=factor for single line 3-inch hose using $1\frac{1}{2}$-inch open nozzle.

2=number of lengths of 3-inch hose from standpipe outlet on 10th floor.

$$
\begin{array}{r}
.192 \\
2 \\
\hline
.384 \\
1.1 \\
\hline
1.484 \\
75 \\
\hline
7420 \\
10388 \\
\hline
111.300
\end{array}
$$

(75 lbs. nozzle pressure on $1\frac{1}{2}$-inch nozzle)

or 111 pounds pressure at standpipe outlet on 10th floor.

The distance from the 10th floor standpipe outlet to the 8th floor standpipe is 24 feet (allowing 12 feet to a floor).

$$
\begin{array}{r}
2.304)24.000(10.4 \\
2304 \\
\hline
9600 \\
9216 \\
\hline
\end{array}
$$

10.4 lbs. gained by water falling 24 feet + 111 pounds pressure at 10th floor outlet = 121.4 pounds pressure at standpipe outlet on 8th floor.

.351=factor for single line 3-inch hose using $1\frac{3}{4}$-inch open nozzle.

2=lengths of 3-inch hose from standpipe outlet on 8th floor.

$$
\begin{array}{r}
.351 \\
2 \\
\hline
.702 \\
1.1 \\
\hline
\end{array}
$$

1.802 divided into 121.4 pounds pressure at outlet on 8th floor=67 pounds nozzle pressure.

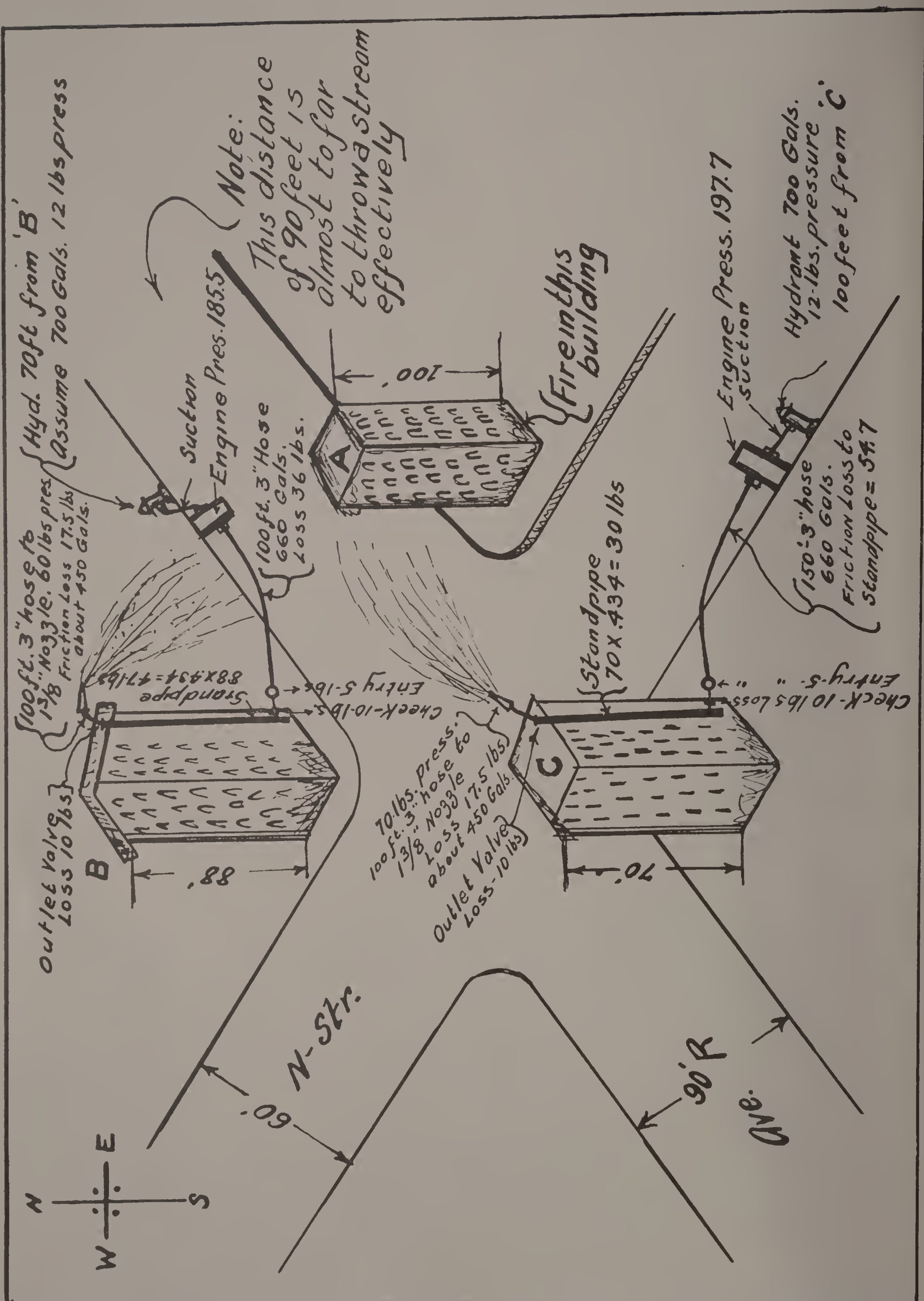
Total friction loss:

Pressure in pounds per square inch at 10th floor outlet=111 pounds. Allowing 12 feet to a floor, from street to standpipe outlet on 10th floor= 114 feet×.434 pounds=49.4 pounds.

Loss in inlet, swing check, outlet, bends and 114 feet 6-inch standpipe discharging 1,321 gallons, etc.=approximately 25 pounds. 150 feet 3-inch hose from engine to standpipe, each line discharging 660 gallons=54.7 pounds; or 240 pounds pressure per square inch on each engine, 240.1 pounds.

NOTE:—The largest size engine in the Department is an extra, extra first size, capable of delivering 1,100 gallons of water per minute at 120 pounds pump pressure and 50 per cent. of the rated capacity at 200 pounds pressure; so each engine will deliver 550 gallons per minute at 240 pounds pressure if in first-class condition, making a total of 1,100 gallons of water discharged per minute, using two extra, extra first size engines; but we are required to obtain 1,321 gallons of water per minute. Thus it can readily be seen there is no engine in the Department capable of delivering more than 550 gallons of water per minute at 200 pounds net pressure.

Good practice requires the use of a nozzle which should never be larger than one-half the diameter of the hose; a 1¾-inch nozzle is too large to be used on a 3-inch line. A smaller size nozzle should be used, preferably a 1⅜-inch and 1¼-inch to throw a stream across a 60-foot street.


N
W
E
S
Outlet Valve Loss 10 lbs.
100 ft. 3" hose to 1 3/8" Nozzle. 60 lbs pres. Friction Loss 17.5 lbs about 450 Gals.
Hyd. 70ft from 'B' Assume 700 Gals. 12 lbs press
B
88'
Standpipe 88X.434=47 lbs
Suction
Engine Pres. 185.5
Note: This distance of 90 feet is almost to far to throw a stream effectively
100 ft. 3" Hose 660 Gals. Loss 36 lbs.
A
100'
60'
N-Str.
Check-10-lbs
Entry 5-lbs
70 lbs. Press. 100 ft. 3" hose to 1 3/8" Nozzle Loss 17.5 lbs about 450 Gals.
Outlet Valve Loss-10 lbs
C
Fire in this building
Standpipe 70X.434=30 lbs
70'
90' R
Ave.
Check-10 lbs Loss
Entry-5- "
Engine Press. 197.7
Suction
Hydrant 700 Gals. 12-lbs. pressure 100 feet from 'C'
150'-3" hose 660 Gals. Friction Loss to Standpipe = 54.7

Loss of pressure from engine to top of building "B"

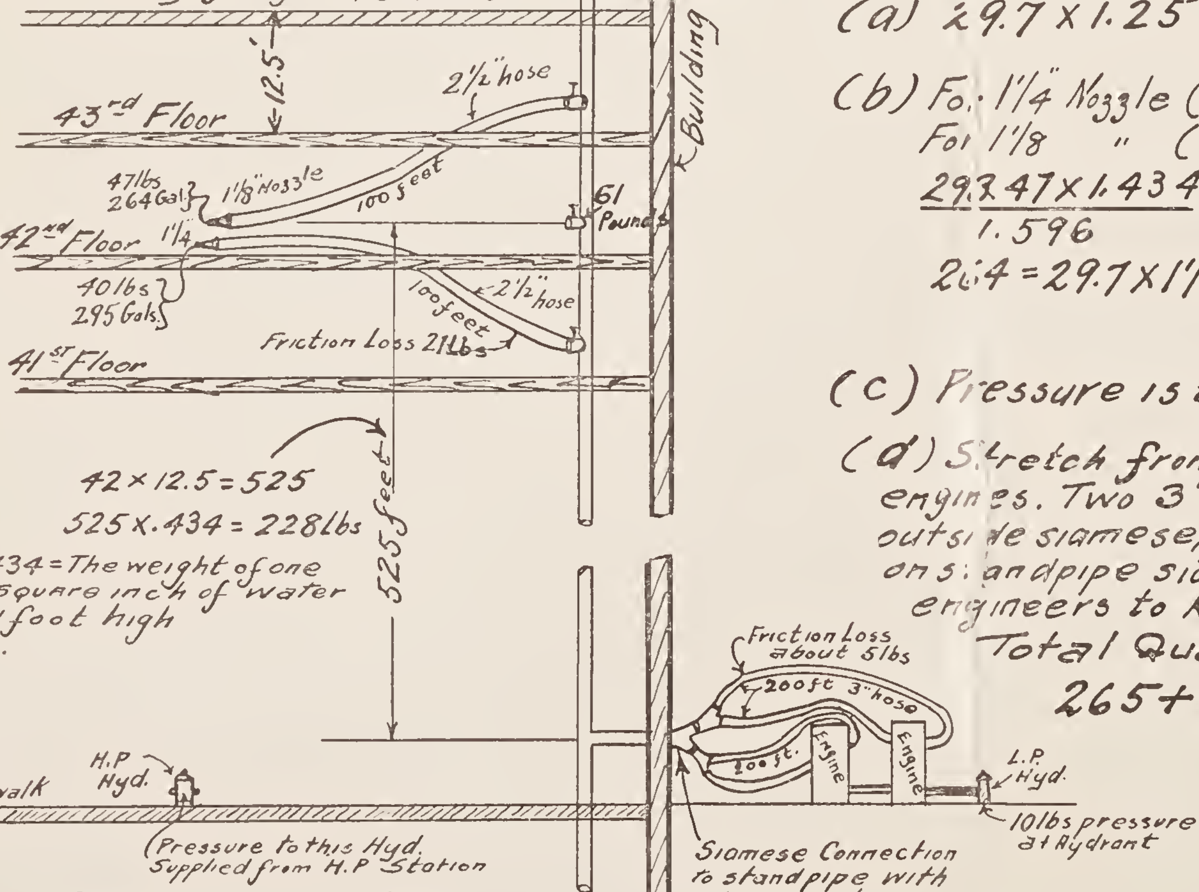
100 ft. 3" hose from Eng. to standpipe	= 36 lbs.
Loss at Entry	5 "
" " Swing Check	10 "
" " Outlet Valve	10 "
Standpipe = 88 x .434	47 "
100 ft. 3" hose to Nozzle	17.5
Nozzle Pressure	60.0
Engine Press. =	185.5

Loss of pressure from engine to top of building "C"

150 ft. 3" hose from engine to S.P.	= 54.7
Loss at Entry	5.0
" " Swing Check	10.0
" " Outlet Valve	10.0
Standpipe = 70 x .434	30.0
100 ft. 3" hose to Nozzle	18.0
Nozzle Pressure	70.0
Engine Press. =	197.7

Problem: A building 100 ft. high, called A, stands at the S.E. cor. of N street and Ave R. Opposite A — and across the avenue, which is 90 feet wide, is a building 88 ft. high, called B, and across N street, 60 feet wide, is a building 70 ft. high, called C. There is a hydrant 70 feet from B and another 100 feet from C. Each building has its appropiate standpipe. A fire is raging in A. You wish to fight the fire from the tops of B and C. An engine stands at each hydrant. What pressure would you order at each engine to get effective results? Show how you would figure loss of pressure from one engine to top of building B, and from other to top of C. Assuming that you get a pressure of 60 lbs. to the inch at the nozzle on B, and 70 lbs. at the nozzle on C. What pressure is given at each engine?

Note:
Nozzles being both used on 42nd floor, pressure to hoselines would be approximately the same. The one on 43rd floor would gain in coming down to the 42nd floor in hose line the press. lost in going to 43rd floor in the Standpipe. The one on 41st floor would lose its gain in head by going to the 42nd floor.



Sectional Elevation

Problem:
A fire occurs on 42nd floor of an office building having an 8 inch standpipe with a 2½ inch hose connection on each floor and a siamese steamer connection outside of building. A Low Press. Hydrant capable of supplying 800 gals per minute at ten pounds pressure and a high press hydrant are 15 feet from siamese connection. You require 1⅛" inch and 1¼" inch nozzles on 42nd floor. The 1⅛ inch nozzle is supplied from the 43rd floor, and the 1¼" nozzle from the 41st floor. Each line has 100 feet of 2½ hose. Assume you carry 40 lbs pressure on the 1¼" nozzle and that you require 200 feet of hose to reach from either Hydrant to the siamese connection.

Find
(a) How much water will you discharge through 1¼" Nozzle
(b) What pressure on the 1⅛" Nozzle
(c) What pressure would you carry on High Press. Hydrant
(d) How would you supply the standpipe, and if you use engines what size engines would you use and how would you use them?

Ans.

(a) $29.7 \times 1.25 \times 1.25 \times \sqrt{40} = 293.47$ Gals (say 295)

(b) For 1¼" Nozzle $(1.1 + K \times L) = 1.1 + .248 \times 2 = 1.596$
For 1⅛ " $(1.1 + K \times L) = 1.1 + .167 \times 2 = 1.434$ } See Table of values given for "K"

$\dfrac{293.47 \times 1.434}{1.596} = 264$ (say 265)

$264 = 29.7 \times 1\tfrac{1}{8} \times 1\tfrac{1}{8} \times \sqrt{P}$

$\sqrt{P} = \dfrac{264}{29.7 \times 1\tfrac{1}{8} \times 1\tfrac{1}{8}}$

Press for 1⅛" nozzle = 47 lbs (approximate)

(c) Pressure is to high to use "High Press. Hydrant"

(d) Stretch from two 1st size engines or two 2nd size engines. Two 3" Lines from each engine of 200 feet of hose to outside siamese, putting 2-3 inch by 3 inch siamese connections on standpipe siamese to take the 4 lines, and instruct the engineers to keep up a pressure of (as given above) 295 lbs.
Total Quantity of Water required equals
265 + 295 = 560 Gallons per minute

-Results-	
Nozzle Pressure	40 lbs
Friction Loss in 2½ hose	21 "
Pressure head Loss	228 "
Friction Loss in 3" Feeders	5 "
" " in Siamese, floor Connections & Valve	10 "
	304
Subtract (Hyd. pressure)	10
Net Engine Press =	294

Question:—What do you understand by the term "Distribution System"?

Ans.:—A distribution system includes all mains and lateral pipes, the standpipes and distributing reservoirs, gate valves, meters, services and various connections. The system is so arranged that gate valves control the flow in the various pipe lines, generally at the intersection of streets. This valve control permits water to flow from different lines in case of a shut-off in one street; or, in case of a fire, gate valves can be opened on other lines to permit water to flow from a high service line to a low service line, thereby increasing the flow.

Ques.:—What is the capacity of a single high pressure hydrant? What are the diameters of the several valves on the hydrant? What is the pilot valve, and its use?

Ans.:—The capacity of a high pressure hydrant depends upon the amount of pressure on the water main. The capacity when the pressure at the main is at its highest amounts to about 4,000 gallons per minute. The diameters of the various valves of a high pressure are: Main valve, 6 11-16 inches; pilot valve, 2 5-16 inches; drain valve, ¾ inch; independent valves, 3 inches. In the high pressure hydrants in the section of the zone first installed, the independent valves are 3 inches and 4½ inches. The pilot valve is a small valve placed in the center of the main valve. It is used as a by-pass. The diameter of the main valve is 6 11-16 inches. The surface area of the valve is 31 square inches. The action of the valve is in a downward direction when opening, and the movement is against the course or pressure of water entering the standpipe. Under these circumstances it would be very difficult to make opening against a high pressure. Therefore, the object of the pilot valve is to meet these conditions so that an opening can be effected in any high pressure. The pilot, which is inside of the main valve, equalizes the pressure above and below the main valve, this operation making it easy to cope with any pressure. The pilot valve, located in the center of the main valve, has a diameter of 2 5-16 inches and a surface area of about 4 square inches. The pilot valve in the main valve is so arranged that the first turn of the stem operates the small valve inside only, and therefore allows the water to pass between the pilot valve and the main valve into the standpipe of the hydrant.

Ques.:—(a) Give the various sizes of the high pressure water mains. (b) Size connecting to hydrants, and size of main valve in hydrants, also the number and size of outlets on hydrants. (c) What means are provided so as to allow the main valve to be opened with ease against a pressure of 200 pounds? (d) Are the hydrants referred to apt to freeze in cold weather? Why? (e) How many turns are required to open the main hydrant valve and the various independent valves? In what direction does the valve stem turn to open?

Ans.:—(a) In New York there are the following sizes: 24, 20, 16, 12 and 8-inch hydrant connections. In Brooklyn, 20, 16, 12 and 8-inch hydrant connections.

(b) There is an 8-inch connection to the hydrant. The size of main valves in hydrants is 6 inches. In the old system there were one 4½-inch and three 3-inch outlets. The new system has four 3-inch outlets.

(c) There is a pilot valve in conjunction with the main valve which opens first, allowing the water to enter barrel of the hydrant, thereby equalizing the pressure.

(d) The hydrants are not apt to freeze in winter, because there is a drain valve attached to the hydrant which, upon closing the hydrant, opens into a drain above the valve, thereby taking all water out of the barrel. When hydrant opens, the valve closes.

(e) About 21 or 22 turns are required to open the main valve. In order to open the 4½-inch independent valve, about 20 or 21 turns are required, and then each of the 3-inch valves, about 16 turns are necessary. The valve stem turns to the right.

Ques.:—How would you put the fireboats to work if the high pressure gave out in Manhattan?

Ans.:—To begin with, I would average the number of gallons of water each boat would discharge against a pressure of 200 pounds to the square inch at about 5,000 gallons per minute, and if in charge of a fire where the high pressure pumps gave out and I found it necessary to put the fireboats to work, I would send out a special call by telegraph for the fireboats, Engine Co. Nos. 85-86-87, to proceed to station 299; and I would direct an officer to this point with all haste to direct the commanding officer of those boats to connect two 3½-inch lines to each boat, and stretch same across on West Street, and connect up to the high pressure hydrants that are on the west side of the railroad track on West Street, and start water into the high pressure hydrants.

In connecting those lines it must be remembered that the boat hose is 3½ inches, and the hydrant inlet is 2 inches; so it will be necessary to increase the hydrant inlet to 3½ inches by using an increaser and the use of a 3½-inch double swivel connection to connect hydrant outlet to the male end of 3½-inch hose. Those two tools can be procured from the boat.

In starting the water into the high pressure mains, care must be exercised, for this reason: If all the hydrants were to be opened full and the boats were to start their pumps, the water would drive back to the boat pumps that were not started simultaneously and do great damage to the pumps. For this reason this method should be pursued: Keep all the hydrants, except the first hydrant, closed, and have the first boat start its

water into the high pressure mains first, and after this boat has started its water have the other boats make up the pressure in the line of hose between the boat pump and the high pressure hydrant; and when this is done open the high pressure hydrant and let the pressure flow into the mains. There is only one place for fireboat connection on the west track and the pier line running from Gansevoort to Chambers Street, and at the foot of James Slip, East River.

Ques.:—(a) What determines the size of a tank for a sprinkler system? (b) What is the average flow of water through a sprinkler head?

Ans.:—(a) The capacity of the tank or the number of gallons of water necessary is determined by the floor area to be covered, which in turn determines the number of sprinkler heads on each floor. The product of the number of sprinkler outlets on a floor by the number of gallons of water that will flow through a sprinkler head in a minute when the working pressure is at a maximum, give the least amount of water that the tank may hold. Special conditions in each building will, of course, necessitate departure from this general rule.

(b) The flow of water through a sprinkler head depends upon the pressure present. Under a pressure of 15 pounds to the square inch, the flow will be 20 gallons per minute. At a pressure of 25 pounds per square inch, the flow increases by 3 to 5 gallons per minute. When the water is flowing at a full pressure of 75 pounds to the square inch, from 55 to 60 gallons of water will flow through a sprinkler head in one minute. These amounts have been determined by actual experiment and not by any set rule.

Ques.:—(a) What size standpipe is required in a building in course of erection to be 85 feet in height; (b) for a building in course of erection to be 150 feet in height; (c) for a building in course of erection to be 250 feet in height?

Ans.:—(a) No standpipe is required for a building 85 feet in height.
(b) A building less than 150 feet requires 4-inch standpipe.
(c) Over 150 feet and under 250 feet, must have a 6-inch standpipe.
(d) Over 250 feet, must have 8-inch standpipe.

Ques.:—What is a Smith connection, and describe how it is made.

Ans.:—A Smith connection is an invention used to make connection with intersecting lines of water mains without having to turn off the water, and can be used on the largest mains. It is made by placing the Smith sleeve around the outside of water main to be made, this sleeve to have an inside diameter ¾ of an inch greater than outside diameter of pipe to be cut.

The sleeve has an outlet on it, according to the size of the pipe to which connection is made. This outlet is adjusted to the proper position, then the point on sleeve is equalized all around, and lead wedges

placed so that it will not shift position. The snakes, or clips, are fastened around pipe to be cut on both sides of sleeve, and a snake of lead placed close to main on inside of this outlet, after which the lead is poured into sleeve so that there is a solid joint all through the sleeve. The snakes are then removed and joint is caulked on both sides of sleeve and on the inside of outlet clear of pipe which is to be cut. Then a gate, called a Smith gate, is adjusted to sleeve (at point outside of where pipe is to be cut) by a flange joint.

The gate is then opened, after which a mechanical contrivance called a Smith cutter is used, which is adjusted to gate by flange joints, which has a series of knives arranged in a complete circle the exact size of inside diameter of pipe to which connection is to be made. This cutter has a long shaft and two ratchets.

On the other end of pipe a nearly solid iron cap is placed, which has a hole in center through which this shaft passes, this cap being adjusted to cutter with iron flanges. The cutter is then forced through gate up to main, with knives hard against main; then levers are put on two ratchets, and one man is placed on setscrew to regulate the cutting. The ratchets are manipulated until the knives have cut the piece of iron out the size wanted, when the shaft is withdrawn so that the knives can reach inside of iron cap above mentioned. After this the gate is closed. The cap and cutter are removed with practically no loss of water. The gate and the sleeve stay on main, after which all is ready to connect to this gate.

The time consumed depends upon the thickness, hardness and size of piece to be cut; also under what conditions the men have for the free use of working ratchet on account of sub-surface structures in the street. Sometimes on account of these structures, it becomes obligatory to use the main shaft only for cutting; therefore, the time consumed is longer.

SIAMESED LINES.

A fairly common form of example in hose layouts is one involving siamesed lines, or a line made up of two different sizes of hose. These can be worked most easily by reducing the siamesed lines or the different sizes of hose all to an equivalent length of 2½-inch hose; that is, to a length of 2½-inch hose which will give the same total friction loss as the siamesed line or the combined lines. To enable this to be done, certain factors have been determined, based upon the relative friction loss of the different sizes and combination of hose. These factors (f) are given below:

Single Lines.

2¾″	3″	3½″	4″	4½″	5″
f=1.66	2.6	5.8	11.0	19.5	32.0

Siamesed Lines of Equal Length.

2-2½″	3-2½″	2-3″	3-3″	1-3″, 1-2½″
f=3.6	7.75	9.35	20.4	6.1

Example indicating the use of factors: From a high pressure hydrant, one 400-foot line of 2½-inch hose and one 400-foot line of 3-inch hose are siamesed into a 600-foot line of 3-inch hose, which connects to a 400-foot line of 2½-inch hose having a 1¼-inch tip; what pressure will be necessary at the hydrant to give 50 pounds nozzle pressure?

The factor for siamesed lines of 3 inches and 2½ inches is 6.1; then the length of 2½-inch hose equivalent to the 400 feet of siamesed lines is

$\frac{400}{6.1}$, or 65 feet.

The factor for 3-inch hose is 2.6; then the length of 2½-inch hose equivalent to the 600 feet of 3-inch is $\frac{600}{2.6}$, or 230 feet.

Therefore, the total equivalent 2½-inch line is 65+230+400 feet, or 695 feet, which can be assumed as 14 lengths.

Using the constant (K) for 1¼-inch nozzle, as given in table of the National Board of Fire Underwriters, we solve the problem as follows:

$$\begin{aligned}\text{Engine Pressure} &= 50\ (1.1+.248\times14)\\ &= 50\ (1.1+3.47)\\ &= 50\times4.57\\ &= 228 \text{ pounds.}\end{aligned}$$

For siamesed lines of hose of same diameter, but of different length, the following rules may be used:

Siamesed line, one twice as long as the other, equal one line one-third the length of the shortest.

Example:—One line 300 feet and one line 600 feet siamesed are equal to one line 100 feet long.

Siamesed lines, one three times as long as the other, equal one line 0.4 the length of the shortest.

Example:—One line 500 feet and one line 1,500 feet siamesed are equal to one line 0.4×500, or 200 feet long.

For the problem involving a single line of hose branching into two lines, each with a separate nozzle, it is necessary to find the length of a single line having the same friction loss as the two parallel lines, and the size of a single nozzle equivalent to the two on the lines in question. Equivalent nozzle sizes may be computed from the nozzle areas, and the equivalent length of a single line may be found by the use of the factors given in the preceding problem.

It is not always possible to find a nozzle size for use in the formula which is the exact equivalent of two or more smaller nozzles, but a close approximation can usually be made.

For an example indicating the method of working out this problem, consider a single 500-foot line of 3-inch hose branching into two 300-foot lines of 2½-inch hose, each with a 1⅛-inch nozzle. Assume a pressure of 150 pounds at the engine, and determine the nozzle pressure.

Two 1⅛-inch nozzles are approximately the equivalent of one 1⅝-inch nozzle.

The factor of 3-inch hose is 2.6, and the length of 2½-inch hose equivalent to 500 feet of 3-inch is $\frac{500}{2.6}$, or 192 feet.

The factor for two lines of 2½-inch hose is 3.6, and the length of a single line of 2½-inch hose equivalent to two 300-foot lines is $\frac{300}{3.6}$, or 83 feet.

This combination of hose and nozzle is, therefore, the equivalent to, that is, will deliver about the same amount of water as a $1\frac{5}{8}$-inch nozzle on the end of a line of $2\frac{1}{2}$-inch hose. 192+83 feet long equals 275 feet. Using the formula given previously, we have then:

$$\text{Nozzle Pressure equals } \frac{150}{1.1+5.5\times 0.68} \text{(equals 31 pounds).}$$

By using previous rules to determine the discharge at 31 pounds nozzle pressure through a $1\frac{1}{8}$-inch nozzle, and to determine the friction loss in 500 feet of 3-inch hose and two 300-foot lines of $2\frac{1}{2}$-inch hose, we find that the solution is not exactly correct, since the 31 pounds nozzle pressure in the problem above will actually require, allowing about 3 pounds loss at the engine outlet and the same at the "Y" branch, only 146 pounds engine pressure. The error in this case arises from the fact that the two $1\frac{1}{8}$-inch nozzles are not quite the equivalent of one $1\frac{5}{8}$-inch. The solution of the problem given above is, however, sufficiently close for all practical purposes.

(From data compiled by Mr. George W. Booth, Chief Engineer, National Board of Fire Underwriters.)

FIRE STREAM TABLES.

(From "Fire Engine Tests and Fire Stream Tables," published by permission of the National Board of Fire Underwriters.—Copyrighted.)

These tables are arranged to show the pressures required at the hydrant or fire engine, while stream is flowing, to maintain nozzle pressures given in the first columns, through various lengths of 2½, 3 and 3½-inch rubber-lined hose in single lines and two lines of 2½-inch hose siamesed.

Nozzle pressures of 40 to 60 pounds from 1⅛ and 1¼-inch nozzles will give streams which may be classed as good and which can be handled without special appliances; for deluge sets, turret pipes, etc., with 1½-inch and larger nozzles, 60 to 90 pounds nozzle pressure is desirable for effective fire-fighting; the height, area and general character of the building are factors in determining at what pressure a stream may be considered good, as well as in determining whether a nozzle is of sufficient size to furnish an effective stream, nothing less than 1⅛-inch being considered as effective for outside work, except for fires in small buildings In this connection it should be noted that a 1 or 1⅛-inch ring tip delivers a stream about ⅛ inch smaller than the diameter of the tip.

The pressure at the hydrant or fire engine is that indicated by a gage attached to the hydrant or fire engine while the stream is flowing. The pressure at the nozzle is that indicated by a Pitot gage held in the stream.

The hydrant (or engine) pressures are obtained by adding to the nozzle pressure the friction loss in the hose, and also the small additional loss in the hydrant outlet or engine discharge.

Friction losses in hose are based on tests of best quality rubber-lined fire hose and are for 100-foot lengths measured without pressure applied. Diameters of hose, as measured under 75 pounds pressure, assumed as the average working condition, were as follows: For nominal 2½-inch, 2.575 or about 2 9-16 inches; for nominal 3-inch, 3.125 or 3⅛ inches; for nominal 3½-inch, 3.685 or about 3 11-16 inches.

The smoothness of the lining has a very considerable effect on the friction loss, some samples tested showing losses 50 per cent. in excess of those given. A slight variation in diameter also produces a marked difference in friction loss; in the case of 2½-inch hose, a variation of 1-16 inch in diameter will result in 10 per cent. difference in loss. If properly beveled 2½-inch couplings are used on 3-inch hose, the loss of pressure due to them will be less than 5 per cent. of that gained by the use of

the larger hose. For instance, for a flow of 300 gallons per minute, the loss in 2½-inch hose will be about 21 pounds, in 3-inch hose with 3-inch couplings about 8 pounds, and in 3-inch with 2½-inch couplings about 8½ pounds.

For siamesed lines, an allowance was made for the loss in the siamese connection and for 20 feet of 3½-inch lead hose.

The pressures given are for the nozzle at the same elevation as the hydrant or engine discharge outlet. Add or subtract 1 pound to the pressure given for each 2 1-3 feet difference in elevation. The arrangement of the table allows a comparison to be readily made of the results obtainable with 3-inch hose and siamesed lines against single lines of 2½-inch hose.

TABLE OF NOZZLE FACTORS.

(From "Fire Engine Tests and Fire Stream Tables," published by permission of the National Board of Fire Underwriters.—Copyrighted.)

For use in obtaining discharge from smooth nozzle larger than those given in tables on pages 58 and 59, when nozzle pressure is obtained with a Pitot gage.

The discharge in gallons per minute is equal to the square root of the pressure multiplied by the factor.

Diameter of the nozzle in inches.	Factors. For Fresh Water.	Factors. For Salt (sea) Water.
2	118.96	117.45
2¼	150.56	148.64
2½	185.88	183.50
2¾	224.91	222.05
3	267.66	264.25
3¼	314.13	310.13
3½	364.32	359.68
3¾	418.23	412.90
4	475.85	469.79
4¼	537.19	530.35
4½	602.25	594.58
4¾	671.02	662.48
5	743.51	734.03
6	1,070.64	1,057.00

For any size nozzles, the discharge, for fresh water, can be determined by the following formula:

Gallons per minute$=29.83\ c\ d^2\ \sqrt{p}$.

Where d=diameter of nozzle in inches, measured to 1-1000 of an inch.

p=pressure recorded on Pitot gage in pounds.

c=a constant, varying from 0.990 for 1-inch nozzle to 0.997 for 6-inch nozzle.

For ordinary use, the formula can be reduced to:

Gallons per minute$=29.7\ d^2\ \sqrt{p}$.

DISCHARGE TABLE FOR SMOOTH NOZZLES.

NOZZLE PRESSURE MEASURED BY PITOT GAGE.

Nozzle Pressure in lbs. per sq. inch.	Nozzle Diam. in Inches. 1	1⅛	1¼	1⅜	1½	Nozzle Pressure in lbs. per sq. inch.	Nozzle Diam. in Inches. 1	1⅛	1¼	1⅜	1½
	Gallons per minute.						Gallons per Minute.				
5	66	84	103	125	149	60	229	290	357	434	517
6	72	92	113	137	163	62	233	295	363	441	525
7	78	99	122	148	176	64	237	299	369	448	533
8	84	106	131	158	188	66	240	304	375	455	542
9	89	112	139	168	200	68	244	308	381	462	550
10	93	118	146	177	211	70	247	313	386	469	558
12	102	130	160	194	231	72	251	318	391	475	566
14	110	140	173	210	249	74	254	322	397	482	574
16	118	150	185	224	267	76	258	326	402	488	582
18	125	159	196	237	283	78	261	330	407	494	589
20	132	167	206	250	298	80	264	335	413	500	596
22	139	175	216	263	313	82	268	339	418	507	604
24	145	183	226	275	327	84	271	343	423	513	611
26	151	191	235	286	340	86	274	347	428	519	618
28	157	198	244	297	353	88	277	351	433	525	626
30	162	205	253	307	365	90	280	355	438	531	633
32	167	212	261	317	377	92	283	359	443	537	640
34	172	218	269	327	389	94	286	363	447	543	647
36	177	224	277	336	400	96	289	367	452	549	654
38	182	231	285	345	411	98	292	370	456	554	660
40	187	237	292	354	422	100	295	374	461	560	667
42	192	243	299	363	432	105	303	383	473	574	683
44	196	248	306	372	442	110	310	392	484	588	699
46	200	254	313	380	452	115	317	401	495	600	715
48	205	259	320	388	462	120	324	410	505	613	730
50	209	265	326	396	472	125	331	418	516	626	745
52	213	270	333	404	481	130	337	427	526	638	760
54	217	275	339	412	490	135	343	435	536	650	775
56	221	280	345	419	499	140	350	443	546	662	789
58	225	285	351	426	508	145	356	450	556	674	803
60	229	290	357	434	517	150	362	458	565	686	817

Assumed coefficient of discharge per cent. = .99 .99 .99 .99¼ .99½

NOTE.—Coefficients of discharge are based on experiments by Mr. John R. Freeman, *Transactions* Am. Soc. C. E., Vols. XXI and XXIV.

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DISCHARGE TABLE FOR SMOOTH NOZZLES.

NOZZLE PRESSURE MEASURED BY PITOT GAGE.

Nozzle Pressure in lbs. per sq. inch.	Nozzle Diam. in Inches. 1⅝	1¾	1⅞	2	2¼	Nozzle Pressure in lbs. per sq. inch.	Nozzle Diam. in Inches. 1⅝	1¾	1⅞	2	2¼
	Gallons per Minute.						Gallons per Minute.				
5	175	203	234	265	337	60	607	704	810	920	1167
6	192	223	256	292	369	62	617	716	823	936	1187
7	207	241	277	315	399	64	627	727	836	951	1206
8	222	257	296	336	427	66	636	738	850	965	1224
9	235	273	314	357	452	68	646	750	862	980	1242
10	248	288	330	376	477	70	655	761	875	994	1260
12	271	315	362	412	522	72	665	771	887	1008	1278
14	293	340	391	445	564	74	674	782	900	1023	1296
16	313	364	418	475	603	76	683	792	911	1036	1313
18	332	386	444	504	640	78	692	803	924	1050	1330
20	350	407	468	532	674	80	700	813	935	1063	1347
22	367	427	490	557	707	82	709	823	946	1076	1364
24	384	446	512	582	739	84	718	833	959	1089	1380
26	400	464	533	606	769	86	726	843	970	1102	1396
28	415	481	554	629	799	88	735	853	981	1115	1412
30	429	498	572	651	826	90	743	862	992	1128	1429
32	443	514	591	673	854	92	751	872	1002	1140	1445
34	457	530	610	693	880	94	759	881	1012	1152	1460
36	470	546	627	713	905	96	767	890	1022	1164	1476
38	483	561	645	733	930	98	775	900	1032	1176	1491
40	496	575	661	752	954	100	783	909	1043	1189	1506
42	508	589	678	770	978	105	803	932	1070	1218	1542
44	520	603	694	788	1000	110	822	954	1095	1247	1579
46	531	617	710	806	1021	115	840	975	1120	1275	1615
48	543	630	725	824	1043	120	858	996	1144	1303	1649
50	554	643	740	841	1065	125	876	1016	1168	1329	1683
52	565	656	754	857	1087	130	893	1036	1191	1356	1717
54	576	668	769	873	1108	135	910	1056	1213	1382	1750
56	586	680	782	889	1129	140	927	1076	1235	1407	1780
58	596	692	796	905	1149	145	944	1095	1257	1432	1812
60	607	704	810	920	1168	150	960	1114	1279	1456	1843

Assumed coefficient of discharge per cent. = .995 .995 996 .997 .997

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AUTOMOBILE AND GASOLENE-DRIVEN FIRE ENGINES.

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In so far as they apply, the same tests are desirable for automobile and other gasolene motor pumping engines as for steam fire engines, so that the same methods for measuring the water discharged, calibrating (testing) water gages, calculating the actual and normal displacement and slip of the pumps and averaging the net water pressure may be used. High pressure, valve and suction tests may also be made in much the same way as on steam fire engines.

Owing to the characteristics of the internal combustion engine certain additional tests and modifications will be found advantageous. A capacity test should be run longer than is usually necessary with a steam engine. It is suggested that for acceptance, engines of this type be required to deliver their full rated capacity of 120 pounds average net pressure for 2 hours, and 50 per cent. of their rated capacity at 200 pounds net pressure for 1 hour. Tests should preferably be made when drafting with at least 10 feet of lift, especially if the engine may be required to take suction from a river, canal or cistern when in service. The tables of "Hose and Nozzles for Testing Engines, Using Siamesed Lines" and of "Nozzles for Testing Engines, Using Single 50-foot Lines of Hose" (given elsewhere in this book), may be used to determine the lengths of hose and size of nozzle to be used, with an engine of a given or guaranteed capacity. If two streams are preferred for such tests, other tables of the Underwriters will be found convenient in laying out the length of hose and size of nozzles to be used.

Additional tests with a line about 300 feet in length, with a shut-off nozzle, are desirable. The nozzle should be closed with the engine pumping at 120 pounds pressure and then at 200 pounds. The relief valve should be set to operate at about 10 pounds higher than the pressure to be carried, and when the nozzle is closed should permit the engine to run with an increase of not over 30 pounds pressure; the motor should not stall. The motor should start the pump readily with the hand relief valve open and discharge gates closed.

A. L. A. M. Formula for Horse-Power of Gasolene Motors.

$$\text{Horse-Power} = \frac{\text{Bore} \times \text{Bore} \times \text{No. of Cylinders}}{2.5}$$

Example:—Six-cylinder motor, 4½-inch bore.

$$\text{H-P.} = \frac{4\frac{1}{2} \times 4\frac{1}{2} \times 6}{2.5} = 48.6.$$

Reasonable Capacities of Modern Fire Engines.

Bore of Pumps, Inches.	Stroke, Inches.	Capacity, Gallons per Minute.
6	9	1,100
5¾	8 or 9	1,000
5½	8	900
5¼	8 or 9	850
5	8	750
4¾	8	700
4½	7 or 8	600
4¼	7 or 8	550
4	7	500

Rated Capacity of Silsby Engines.

Maker's Size.	Nominal Displacement per Revolution, Gallons.	Rated Capacity, Gallons per Minute.
Extra First	1.261	1,000
First	1.141	900
Second	0.952	700
Third	0.804	600
Fourth	0.675	500
Fifth	0.513	400

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ENGINE DISPLACEMENT TABLE.

DOUBLE PUMPS.

Plunger Displacement. Gallons per Revolution.

Bore of Pump Inches.	Stroke in Inches. 7	8	9
3 1/2	1.166	1.333	1.500
3 5/8	1.251	1.430	1.609
3 3/4	1.339	1.530	1.721
3 7/8	1.430	1.634	1.838
4	1.523	1.740	1.958
4 1/8	1.620	1.851	2.082
4 1/4	1.719	1.965	2.211
4 3/8	1.822	2.083	2.343
4 1/2	1.928	2.203	2.478
4 5/8	2.036	2.327	2.618
4 3/4	2.148	2.455	2.762
4 7/8	2.263	2.586	2.909
5	2.380	2.720	3.060
5 1/8	2.500	2.858	3.215
5 1/4	2.624	2.999	3.374
5 3/8	2.750	3.143	3.536
5 1/2	2.880	3.291	3.702
5 5/8	3.012	3.442	3.872
5 3/4	3.147	3.597	4.047
5 7/8	3.286	3.755	4.225
6	3.427	3.917	4.407

Pump Rod Correction. Gallons per Revolution.

Diameter of Pump Rods.	Stroke in Inches. 7	8	9
1 "	0.047	0.054	0.061
1 1/16	0.053	0.061	0.069
1 1/8	0.060	0.069	0.078
1 3/16	0.067	0.077	0.087
1 1/4	0.074	0.085	0.096
1 5/16	0.081	0.093	0.105
1 3/8	0.089	0.102	0.115
1 7/16	0.098	0.112	0.126
1 1/2	0.107	0.122	0.138
1 9/16	0.116	0.133	0.150
1 5/8	0.126	0.143	0.162
1 11/16	0.136	0.155	0.174
1 3/4	0.146	0.167	0.188

Subtract pump rod correction from plunger displacement to obtain correct displacement of engine.

For single-pump engines, use one-half of result obtained.

For single-acting pumps, do not subtract pump rod correction.

Example: Engine with 5¼-inch pump, 9-inch stroke and 1½-inch pump rod.

From Table above:

Displacement of Plunger = 3.374 gallons.
Correction for Rod = 0.138 gallons.

Nominal Displacement = 3.236 gallons

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Below is given a table for use when engines are worked at draft, either in actual service or in testing. A study of it will show that where a high lift is necessary, small suctions will restrict the capacity of an engine; the table indicates clearly what sizes are necessary under different conditions. The figures are based on the ability of the pumps to maintain a vacuum of 23 inches.

TABLE SHOWING MAXIMUM LIFT, IN FEET, WHEN DRAFTING VARIOUS QUANTITIES OF WATER WITH A FIRE ENGINE IN GOOD CONDITION.

Quantity of Water, Gallons per Minute.	Maximum Lift in Feet, Engine Drafting.					
	3" Suction.	3½" Suction.	4" Suction.	4½" Suction.	5" Suction.	
300	16	20	22½	24	24½	3 lengths of suction.
400	8½	17	20	22½	24	
500		12½	18½	20½	23	
600		7	15	19½	21	
700		4½	11	17	19½	
800			6½	14½	19	2 lengths of suction.
900			6	11½	17	
1,000				8	14½	
1,100				7½	12	
1,200				4	9½	
1,300					6½	
1,300	1 length of suction.				9½	

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TABLE OF HOSE AND NOZZLES FOR TESTING ENGINES, USING SIAMESED LINES.

NOTE.—Connect Lines to a Deluge Set Provided with a Short Lead of 3½- or 4-Inch Hose. Use Only Smooth-Bore Nozzle and of the Diameter Given. By Regulating One of the Discharge Gates, Pressure can be Kept Nearly Constant and from Three-quarters to Full Capacity Obtained

Size.	Bore of Pump.	Reasonable Capacity, Gallons per Minute.*	Number and Length of Lines and Size of Nozzle Needed to Deliver the Reasonable Capacity at the Desired Pressure at the Engine.			
			100 Pounds.	120 Pounds.	140 Pounds	160 Pounds.
Double Extra First	6"	1,100	2–50' lines of 3" or 3–50' lines of 2½" 2" Nozzle	2–100' lines of 3" or 3–100' lines of 2½" 2" Nozzle	2–150' lines of 3" or 3–150' lines of 2½" 2" Nozzle	2–200' lines of 3" or 3–200' lines of 2½" 2" Nozzle
Extra First	5¾"	1,000	2–50' lines of 2½" 2" Nozzle	1–100 line of 2½" and 1–50' line of 2½" 2" Nozzle	2–100' lines of 3" 2" Nozzle	2–150' lines of 2½" 2" Nozzle
First	5½"	*900	2–50' lines of 2½" 1⅞" or 2" Nozzle	1–100' line of 2½" and 1–50' line of 2½" 1⅞" Nozzle	2–100' lines of 2½" 1⅞" Nozzle	2–150' lines of 2½" 1⅞" Nozzle
Second	5"	750	2–50' lines of 2½" 1¾" Nozzle	2–100' lines of 2½" 1¾" Nozzle	2–150' lines of 2½" 1¾" Nozzle	2–250' lines of 2½" 1¾" Nozzle
	4¾"	700	2–50' lines of 2½" 1⅝" Nozzle	2–100' lines of 2½" 1⅝" Nozzle	2–150' lines of 2½" 1⅝" Nozzle	2–250' lines of 2½" 1⅝" Nozzle
Third	4½" or 4¼"	600 or 550	1–100' line of 2½" and 1–150' line of 2½" 1⅝" Nozzle	1–100' line of 2½" and 1–150' line of 2½" 1½" Nozzle	1–100' line of 2½" and 1–200' line of 2½" 1½" Nozzle	2–250' lines of 2½" 1½" Nozzle
Fourth	4"	500	2–100' lines of 2½" 1⅜" Nozzle	2–200' lines of 2½" 1⅜" Nozzle	2–300' lines of 2½" 1⅜" Nozzle	1–100' line of 2½" 1⅜" Nozzle ‡
Fifth	3⅝"	400	2–100' lines of 2½" 1¼" Nozzle	1–100' line of 2½" 1¼" Nozzle ‡	1–150' line of 2½" 1¼" Nozzle ‡	1–200' line of 2½" 1¼" Nozzle ‡

* Based on about 400' piston travel per minute. ‡ Single lines; deluge set omitted.

NOTE.—If hose has not smoothest lining, shorter lines or a larger nozzle may be required; if hose is slightly larger than given on page 20, it may be necessary to use longer lines or a smaller nozzle.

TABLE OF NOZZLES FOR TESTING ENGINES, USING SINGLE 50-FOOT LINES OF HOSE.

NOTE.—Connect Line to Nozzle; Bring Engine to Speed and Regulate Discharge Gate; if Desired Pressure Cannot be Obtained, Use Nozzle ⅛" Smaller or Add Another Length of Hose.

Size.	Bore of Pump.	Reasonable Capacity, Gallons per Minute.*	Size of Nozzle Needed to Deliver the Reasonable Capacity at the Desired Pressure at the Engine.			
			100 Pounds.	120 Pounds.	140 Pounds.	160 Pounds.
			Single 50-foot Line of 3" hose			
First	5½"	900	2¼"	2¼" or 2"	2"	1⅞" or 1¾"
			Single 50-foot Line of 2½" hose			
Second	5" 4¾"	750 700	2" 1⅞"	1⅞" 1¾"	1⅞" 1¾"	1⅝" 1⅝"
Third	4½" 4¼"	600 550	1¾" or 1⅝" 1⅝"	1⅝" or 1½" 1½"	1½" 1⅜"	1⅜" 1⅜"
Fourth	4"	500	1½"	1⅜"	1⅜"	1¼"
Fifth	3⅝"	400	1¼"	1¼"	1⅛"	1⅛"

* Based on about 400' piston travel per minute.

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MISCELLANEOUS TABLES.

Feet Head of Water and Equivalent Pressure.

Feet Head	Pounds Per Sq. In.	Feet Head	Pounds Per Sq. In.	Feet Head	Pounds Per Sq. In.
1	.43	60	25.99	200	86.62
2	.87	70	30.32	225	97.45
3	1.30	80	34.65	250	108.27
4	1.73	90	38.98	275	119.10
5	2.17	100	43.31	300	129.93
6	2.60	110	47.64	325	140.75
7	3.03	120	51.97	350	151.58
8	3.40	130	56.30	400	173.24
9	3.90	140	60.63	500	216.55
10	4.33	150	64.96	600	259.85
20	8.66	160	69.29	700	303.16
30	12.99	170	73.63	800	346.47
40	17.32	180	77.96	900	389.78
50	21.65	190	82.29	1,000	433.09

Pressure and Equivalent Feet Head of Water.

Pounds Per Sq. In.	Feet Head	Pounds Per Sq. In.	Feet Head	Pounds Per Sq. In.	Feet Head
1	2.31	40	92.36	170	392.52
2	4.62	50	115.45	180	415.61
3	6.93	60	138.54	190	438.90
4	9.24	70	161.63	200	461.78
5	11.54	80	184.72	225	519.51
6	13.85	90	207.81	250	577.24
7	16.16	100	230.90	275	643.03
8	18.47	110	253.98	300	692.69
9	20.78	120	277.07	325	750.41
10	23.09	125	288.62	350	808.13
15	34.63	130	300.16	375	865.89
20	46.18	140	323.25	400	922.58
25	57.72	150	346.34	500	1154.48
30	69.27	160	369.43	1,000	2308.

FRICTION LOSS IN FIRE HOSE—FOR GIVEN NOZZLE PRESSURES

2½"

DIA. OF NOZZLE	1"		1⅛"		1¼"		1⅜"		1½"		1⅝"		1¾"		2"	
NOZZLE PRESSURE	IN 1ST LENGTH	ALL OTHER LENGTHS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS
20	2½	2½	4½	3½	6¾	5¼	9½	7½	13½	10½	18	14	24½	18½	39	31
30	4½	3½	6¾	5¼	10	8	14	11	19½	15½	26	21	34	27	67	45
40	5½	4½	8	7	13	10	18½	14½	25	20	34	27	44½	35½	75½	58½
50	6½	5½	10½	8½	15½	12½	22½	17½	31	25	42	33	56½	43½	82	—
60	8½	6½	13	10	18	15	26	21	37	29	49½	39½	65½	51½	—	—
70	9½	7½	14½	11½	21	17	31	24	42	34	58	45	76½	59½	—	—
80	10½	8½	17	13	24½	19½	35	27	48	38	66	51	77	—	—	—
90	11½	9½	18½	14½	27½	21½	38½	30½	54½	42½	65	—	85½	—	—	—
100	12½	10½	20	16	29½	23½	43	34	61½	45½	72	—	—	—	—	—

3"

	1		1⅛		1¼		1⅜		1½		1⅝		1¾		2	
NOZZLE PRESSURE	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS
20	1	1	3¼	1¼	2	2	5	3	8	4	9½	5½	12½	7½	20	12
30	—	—	—	—	3	3	7¼	4¼	10	6	14	8	17½	10½	30½	17½
40	2	2	3¾	2¾	4	4	8¾	5¾	12¾	7¾	17½	10½	23½	13½	39½	22½
50					5	5	11	7	15½	9½	21¾	12¾	29	17	47	28
60	3	3	5	4	7¾	5¾	13¼	8¼	18¼	11¼	26¼	15¼	34	20	57	33
70					10½	6½	16½	9½	21	13	30¾	17¾	39½	23½	66	38
80	3½	3½	9	5	11½	7½	17¾	10¾	23¾	14¾	33¾	19¾	46	26	77	43
90					14¾	8¼	20	12	27¼	16¼	37¼	22¼	50	29	86	48
100	4	4	10¼	6¼	17	9	23	13	30	18	42½	24½	55½	32½	73	—

3½"

	1"		1⅛"		1¼"		1⅜"		1½		1⅝		1¾		2	
NOZZLE PRESSURE	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS	IN 1ST LENGTH	ALL OTHERS
20					1	1	2¼	1¼	2	2	3½	2½	5	3	7½	5½
30					1½	1½	2	2	3¾	2¾	5½	3½	6	5	11	8
40					2¾	1¾	3½	2½	4½	3½	7½	4½	9	6	15	10
50					3	2	5	3	6¼	4¼	8¾	5¾	10½	7½	17½	12½
60					3¼	2½	4¾	3¾	7	5	9¾	6¾	13	9	21	15
70					4	3	6¼	4¼	8¾	5¾	11¾	7¾	14½	10½	25	17
80					6¼	3¼	5	5	9½	6½	12	9	17	12	27½	19½
90					5	3¾	6½	5½	10½	7½	14	10	19	13	31½	21½
100					7	4	8	6	12	8	16	11	20½	14½	34	24

Problem: Given 1¼" DIA. Nozzle, 20 lbs Nozzle pressure what is the "Loss of Pressure" due to friction in 8 Lengths of 2½" Hose

(See Table) Loss for 1ST Length = 6¾ lbs
" " 7 Lengths = 7×5¼ = 36¾ "

Total press Loss = 6¾ + 36¾ = 43½ lbs

Note. Friction Loss in 1ST Length is greater than in other lengths, due to the additional loss in play pipe attached to 1ST Length.

RELATIVE DISCHARGING CAPACITIES OF PIPES FLOWING FULL

DIAMETER OF PIPE IN INCHES

DIA. IN Inch. = d	Relative Discharging Capacities = $\sqrt{d^5}$	3	4	5	6	8	10	12	14	16	18	20	22	24	30	36	48
48	15,963									15.59	11.61	8.92	7.03	5.65	3.24	2.05	1
44	12,842								17.5	12.54	9.34	7.17	5.66	4.55	2.61	1.65	
40	10,119							20.23	13.47	9.85	7.34	5.64	4.44	3.57	2.05	1.26	
36	7,776							15.58	8.41	7.59	5.65	4.34	3.42	2.74	1.58	1	
33	6,255.8					34.55	19.78	12.54	8.52	6.11	4.55	3.49	2.75	2.21	1.27		
30	4,929.5					27.09	15.54	9.85	6.54	4.80	3.57	2.74	2.16	1.74	1		
27	3,788				42.95	16.61	9.96	7.59	5.16	3.70	2.75	2.11	1.67	1.34			
24	2,821.8			50.5	32.0	15.58	8.92	5.65	3.84	2.75	2.05	1.57	1.24	1			
22	2,270.2		70.96	40.65	25.73	12.53	7.17	4.55	3.09	2.16	1.65	1.26	1				
20	1,788.9		55.96	32.05	20.29	9.88	5.66	3.58	2.43	1.74	1.30	1					
18	1,374.6		42.01	24.63	15.58	7.25	4.34	2.75	1.87	1.34	1						
16	1,024	65.77	32.01	18.31	11.6	5.65	3.23	2.05	1.39	1							
14	733.4	47.14	22.94	13.15	8.32	4.05	2.32	1.47	1								
12	498.8	32.05	15.6	8.93	5.65	4.75	1.57	1									
10	316.2	20.31	9.88	5.66	3.58	1.74	1										
8	181.0	11.63	5.66	3.24	2.05	1											
6	88.18	5.66	2.75	1.58	1												
5	55.9	3.58	1.75	1													
4	32.00	2.05	1														
3	15.59	1															

PROBLEM: How much water will a 12" pipe carry compared to an 8" pipe both having the same loss of pressure.

Rule: Follow down the first column to 12 then to the right under column marked 8 you find 4.75, which means that a 12 inch pipe will carry 4.75 times as much as an 8 inch pipe, or roughly it takes 5 - 8 inch pipes to given the same capacity as one 12" pipe.

Note: For a given diameter the pressure loss varies directly as the square of the quantity, and for different diameters and the same quantity, inversly as the 5th power of diameters.

Quantity of water carried by pipe of the same length and smoothness of surface, with a given loss of pressure, varies as the square root of the fifth power of the diameter or $\sqrt{d^5}$

Friction of Water in Pipes

Friction-loss in pounds pressure per square inch for each 100 feet of Length in different sizes of clean iron pipe discharging given quantities per minute.

	Sizes of Pipe - Inside Diameter. Inches												
Gals. per Minute	3/4	1	1¼	1½	2	2½	3	4	6	8	10	12	14
5	3.3	0.84	0.31	0.12									
10	13.0	3.16	1.05	0.47	0.12								
15	28.7	6.98	2.38	0.97									
20	50.4	12.3	4.07	1.66	0.42								
25	78.0	19.0	6.40	2.62		0.21	0.10	0.27					
30		27.5	9.15	3.75	0.91								
35		37.0	12.4	5.05									
40		48.0	16.1	6.52	1.60		0.20.						
45			20.2	8.15									
50			24.9	10.0	2.44	0.81	0.35	0.09					
75			56.1	22.4	5.32	1.80	0.74	0.23					
100				39.0	9.46	3.20	1.31	0.33	0.05				
150					21.2	7.0	2.85	0.69	0.10				
200					37.5	12.47	5.02	1.22	0.17				
250						19.66	7.76	1.89	0.26	0.07	0.03	0.01	
300						28.06	11.2	2.66	0.37	0.09	0.04		
350							15.2	3.65	0.50	0.12	0.05	0.02	
400							19.5	4.73	0.65	0.16	0.06		
450							25.0	6.01	0.81	0.20	0.07	0.03	
500							30.8	7.43	0.96	0.25	0.09	0.04	0.017
600								10.60	1.43	0.35	0.12	0.05	
700								14.40	1.91	0.47	0.16	0.07	
750									2.21	0.53	0.18	0.08	
800									2.51	0.61	0.21	0.09	
900									3.17	0.77	0.26	0.11	
1000									3.88	0.94	0.32	0.13	0.062
1250										1.46	0.49	0.20	
1500										2.09	0.70	0.29	0.135
2000											1.23	0.49	0.234
2500												0.77	0.362
3000												1.11	0.515
3500													0.697
4000													0.910

MENSURATION OF SURFACES AND VOLUMES.

Area of triangle=base$\times$½ perpendicular height.

Circumference of circle=diameter$\times$3.1416.

Area of circle=square of diameter$\times$.7854.

Area of surface of cylinder=circumference$\times$length+area of two ends.

To find diameter of circle having given area: Divide the area by .7854, and extract the square root.

To find the volume of a cylinder: Multiply the area of the section in square inches by the length of inches=the volume in cubic inches. Cubic inches divided by 1728=volumes in cubic feet.

Surface of a sphere=square of diameter$\times$3.1416.

Solidity of a sphere=cube of diameter$\times$.5236.

Area of the base of a pyramid or cone, whether round, square or triangular multiplied by one-third of its height=the solidity.

Doubling the diameter of a hose increases its capacity four times.

A "miner's inch" of water approximately equals a supply of 12 U. S. gallons per minute.

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